CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 9F: Floodplain Restoration Opportunity Analysis

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Introduction

This section provides an overview of the attachment and document organization.

1.1 Overview

Ecosystem restoration is a key component of the Central Valley Flood Protection Plan (CVFPP), and actions related to ecosystem restoration have been proposed as part of the CVFPP. This report documents an analysis of the potential for ecosystem restoration of floodplains within the Systemwide Planning Area of the State Plan of Flood Control (SPFC) (Figure 1-1).

To support the identification, development, and implementation of specific restoration actions, a Floodplain Restoration Opportunity Analysis (FROA) was conducted, which is summarized in this report. This FROA identifies areas with greater and/or more extensive potential opportunities for ecological restoration of floodplains. It does so by considering physical suitability; and opportunities and constraints related to existing land cover and land uses, locations and physical condition of levees, locations of other major infrastructure, conservation status of land, and locations that stakeholders are interested in restoring.

To evaluate physical suitability, the concept of floodplain inundation potential (FIP) was applied in a geographic information system (GIS) analysis of corridors along the Sacramento and San Joaquin rivers and their major tributaries. This analysis was selected because of the importance of floodplain inundation for ecosystem functions. To assess physical suitability for restoration actions, the FIP analysis adapted concepts from the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (USACE-HEC) (USACE-HEC, 2009), the Frequently Activated Floodplain concept of Williams et al. (2009), and the Height Above River (HAR) GIS tool of Dilts et al. (2010). FIP analysis identifies areas of floodplain, both directly connected to the river and disconnected from the river (e.g., behind natural or built levees or other flow obstructions) that could be inundated by particular floodplain flows. The flows evaluated by the FROA included a spring flow sustained for at least 7 days and occurring in 2 out of 3 years (a 77 percent chance event), and 50 and 10 percent chance peak flows.

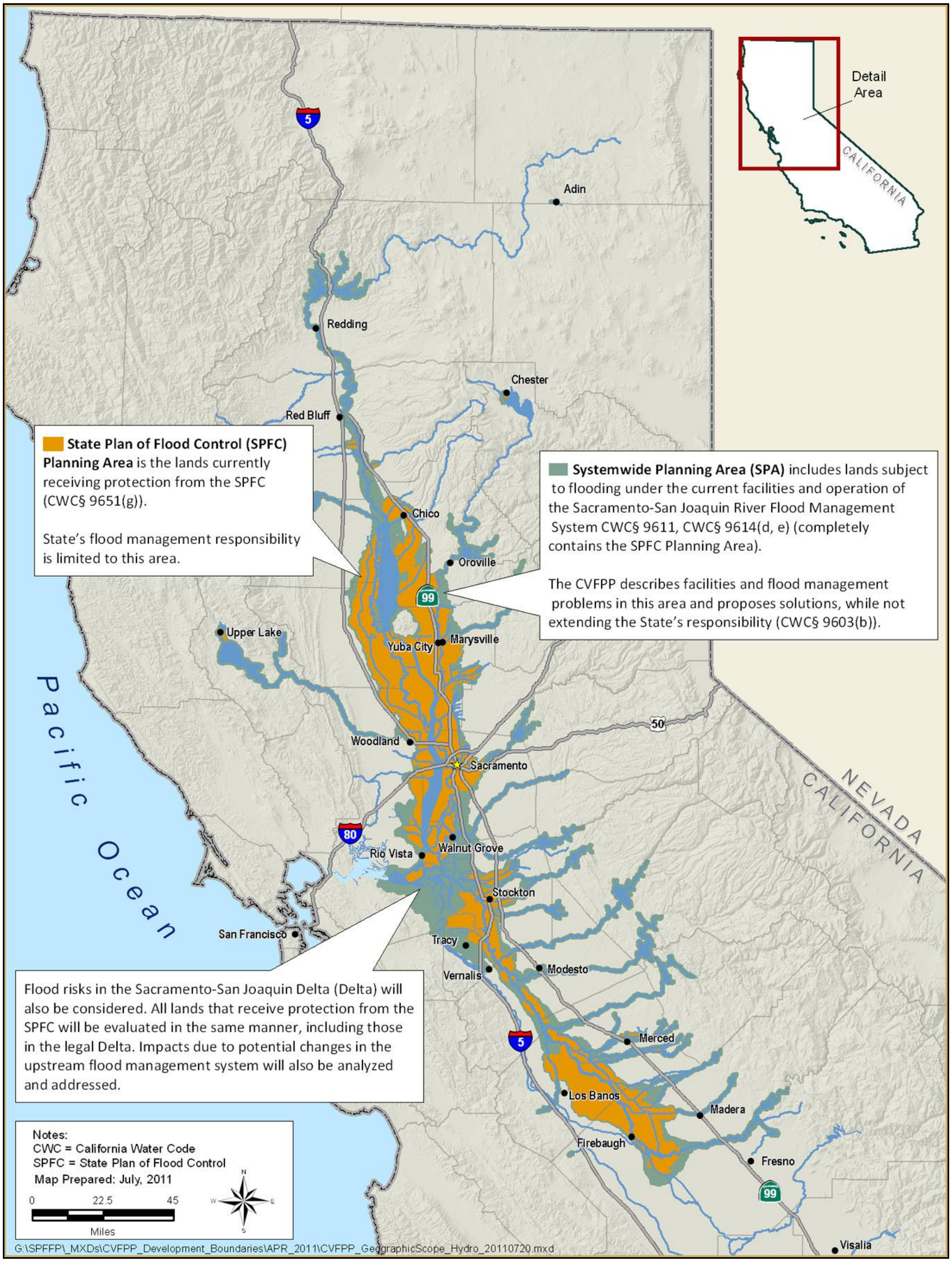

Figure 1-1. Central Valley Flood Protection Plan Planning Area

This analysis adapted existing models and hydrologic data, and thus, the FROA is limited to those reaches of the Sacramento and San Joaquin rivers and their tributaries for which such resources were available. Consequently, the FROA includes the Sacramento River from Woodson Bridge State Recreation Area to Collinsville, the San Joaquin River from Friant Dam to Stockton, the lower Feather River, and the lowermost reaches of other major tributaries of the Sacramento and San Joaquin rivers (i.e., the Bear, Yuba, American, Stanislaus, Tuolumne, and Merced rivers). It does not include smaller tributaries. The Sutter and Yolo bypasses are also included.

For the included river reaches and bypasses, oopportunities and constraints based on existing land use and land cover, major infrastructure locations, and conservation status were determined from existing and available geospatial data for existing wetland and riparian vegetation, Important Farmland (as defined by DOC, 2011), and urban areas; locations of major roads, highways, and railways; and land ownership and management. Four primary categories of existing land use and land cover were considered: developed, irrigated agricultural, open water, and natural; with natural land cover subdivided into wetland, riparian, and upland.

Stakeholder interest in restoration actions was compiled through focused outreach and review of existing reports. Stakeholders were interviewed to document potential ecosystem restoration projects previously identified by various CVFPP stakeholder groups throughout the Systemwide Planning Area. Specific information regarding potential restoration projects identified by stakeholders has been considered confidential. In addition to these interviews, existing reports that identified potential ecosystem restoration opportunities were also reviewed. Projects in reviewed reports that were located within the Systemwide Planning Area and that would provide ecosystem benefits were included with the group of stakeholder-identified projects and areas of interest.

The relationships among areas of physical suitability and opportunities and constraints were used to characterize river reaches and identify reaches with greater and/or more extensive potential opportunities for restoration. Reach boundaries were at junctions with tributaries and other frequently recognized boundaries (e.g., reach boundaries used by the San Joaquin River Restoration Program (SJRRP)).

The results of the FROA are intended to support the subsequent identification, prioritization, and further development of specific restoration opportunities. Through this subsequent planning, specific opportunities would be identified and prioritized on the basis of their potential ecological, flood management, and other benefits (e.g., reduced maintenance and regulatory compliance costs); cost; and regulatory, institutional, technological, and operational feasibility. This process for identifying and prioritizing opportunities would be both part of the continuing development of the overall CVFPP and of the development of species-focused conservation planning and corridor management strategies.

The following report summarizes the methods, results, and recommendations of the FROA.

1.2 Report Organization

The remainder of this attachment is organized into the following sections:

- Section 2.0, Methods
- Section 3.0, Results of the Floodplain Restoration Opportunities Analysis
- Section 4.0, Floodplain Restoration Opportunities: Conclusions and Recommendations
- Section 5.0, References
- Section 6.0, Abbreviations and Acronyms
- Appendix A, Floodplain Inundation and Ecosystem Functions Model Pilot Studies
- Appendix B, Investigation of USGS 10-Meter DEM Accuracy
- Appendix C, CVFED LiDAR Terrain Data Comparisons
- Appendix D, Levee Realignment Methodology
- Appendix E, Synthetic vs. Observed Hydrographs
- Appendix F, HEC-EFM Ecosystem Functional Relationships
- Appendix G, RAS/EFM Analysis FIP-based Mapping

1.3 Acknowledgments

This work was performed for the Floodway Ecosystem Sustainability Branch of the FloodSAFE Environmental Stewardship and Statewide Resources Office, California Department of Water Resources (DWR), and was accomplished by AECOM through Task Order 10-07 to Master Consulting Services Subcontract No. DWR-MSA08-EDAW-AECOM, effective July 26, 2010, with MWH Americas, Inc. (MWH). An independent review of the work was provided by cbec eco engineering, and USACE-HEC responded to technical questions regarding the application of HEC's Ecosystem Functions Model (HEC-EFM). Guidance on the application of the HAR/FIP method was also provided by the author of the software, Thomas Dilts of the University of Nevada, Reno.

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2.0 Methods

2.1 Overview

This chapter describes the general approach and methods of the FROA, which was based in part on the results and conclusions of two pilot studies conducted on the lower Feather River. The specific method used to determine FIP is described in detail in Appendix A, which provides the methods, results, and conclusions of the two pilot studies conducted on the lower Feather River to evaluate the suitability of FIP (an expanded version of the HAR method) (Dilts et al., 2010) and USACE-HEC-FEM (USACE-HEC, 2009) analyses for use in the FROA.

Traditional approaches for analyzing the inundation characteristics of river channel-floodplain land areas typically involve hydraulic models that rely on one-dimensional cross sections to describe the land surface. In addition to the limitations of cross sections to describe land surfaces, these traditional approaches also generally involve a significant amount of time to develop and use. However, because of the large geographic area covered by the CVFPP and the number of potential ecosystem restoration activities within this region, a computational tool capable of rapidly identifying and quantifying habitat restoration opportunities was desired.

Therefore, for this **planning-level study**, a simplified approach was preferred to understand the spatial extent of floodplain land areas that are connected and disconnected from the river channel for certain flow conditions. The FIP method is a GIS-based approach that does this, requires limited field data, is based on simple concepts, and is computationally efficient (Dilts et al., 2010). The FIP approach uses readily available topographic and hydrologic data sets and GIS analyses to identify floodplains potentially inundated under more frequent, ecologically valuable flow events (e.g., 50 and 10 percent chance events). Thus, GIS layers based on the results of the FIP analysis show floodplains that are connected, or could be more readily reconnected, to the river during specific flow events. **The FIP method is not intended to be a replacement for detailed hydraulic models**; instead, it is considered a viable tool for relatively quickly assessing areas that are physically suitable for restoration.

For the purpose of this work, the “FIP method” is the term used to describe the application of GIS tools provided within the ArcGIS Riparian Topography Toolbox, as described by Dilts et al. (2010). The ArcGIS

Riparian Topography Toolbox is distributed by Environmental Systems Research Institute, Inc. (ESRI) (ESRI, 2011). This GIS software uses digital terrain models and water surface elevations from hydraulic modeling to calculate the relative height of terrain above a water surface and the depth of terrain below a water surface (and thus FIP). It also determines the inundated areas that are connected or disconnected from a river channel by levees or other obstructions for a given flow event.

The Floodplain Inundation Pilot Study on the lower Feather River (Appendix A) evaluated the adaptation of the HAR tool for use in this FIP analysis. It found that the FIP method is a relatively effective way to quickly and easily find features on the land surface that are either above or below a specified water-surface profile. Color ramping of GIS layers of FIP output showing height increments both above the river (i.e., water surface) and below can provide a rapid visualization of the low-lying land areas physically connected to a river channel, or capable of being connected, and the relative depth of these topographic depressions. The results can also be used to guide qualitative assessments of potential levee setback locations. Although the FIP method is not a substitute for detailed hydraulic modeling, it does provide an ability to relatively quickly understand flood characteristics across the floodplain landscape.

The FROA is focused on identifying potential restoration areas based on the ecological functions that could be provided by inundated or potentially inundated floodplains. Initially, the Ecosystem Functions Model (HEC-EFM), developed by the USACE-HEC, was considered as a potential tool for identifying the ecological functions provided by inundated and potentially inundated floodplains. HEC-EFM allows criteria (e.g., timing and duration of inundation) to be defined for eco-hydrologic relationships. By applying these criteria to stage and flow hydrographs produced by the HEC's River Analysis System (HEC-RAS), HEC-EFM identifies specific stages and flows providing specific ecological functions to be identified and visualized.

Consequently, a second pilot study, the HEC-EFM Pilot Study, was conducted along the lower Feather River to evaluate use of the HEC-EFM in the FROA. For this pilot study, criteria were developed for the relationship of cottonwood regeneration and salmonid rearing to flow conditions. These criteria were adapted from a previous application of HEC-EFM to support the Sacramento-San Joaquin Comprehensive Study (Comprehensive Study) (USACE and The Reclamation Board, 2002) and from criteria included as part of the Sacramento River Ecological Flows Tool (SacEFT) (ESSA Technologies, 2009). These functions were selected because of their relationship to lower stage floodplains and the limited extent of these habitat functions throughout the Sacramento and San Joaquin river systems.

The methods, results, and conclusions of this pilot study are provided in Appendix A. The study identified several limitations of HEC-EFM for use in the FROA:

- Constraints on the realism of habitat evaluations: (1) use of a single set of criteria as opposed to a range that distinguishes optimal from suboptimal conditions, (2) lack of coupling of relationships (e.g., cottonwood seedling recruitment depends on suitable conditions for germination in spring followed by minimal inundation during the winter), and (3) the potential for varied relationships between ecological functions and hydrologic conditions among the Sacramento and San Joaquin rivers and their tributaries.

- Lack of functional distinctions among evaluated areas: potential habitat for the ecological functions selected was largely absent, resulting in similar habitat attributes; similar results could occur throughout the Sacramento and San Joaquin river systems,

- Cost of application: the time required to apply the HEC-EFM model would limit analysis to selected reaches of the Sacramento and San Joaquin river system.

Consequently, a more generalized approach was developed for identifying floodplain areas where inundation could provide desired ecological functions: four types of flows were used in conjunction with the FIP method to distinguish floodplain areas that could be physically suitable for providing different types or amounts of multiple ecological functions. This approach is described in the following section.

2.2 Floodplain Restoration Opportunity Analysis Approach

As diagrammed in Figure 2-1, the FROA approach consists of three steps:

- Identify Areas of Physical Suitability.
- Identify Opportunities and Constraints.
- Identify Potential Restoration Opportunities.

The methodology of each of these steps is described in the following sections.

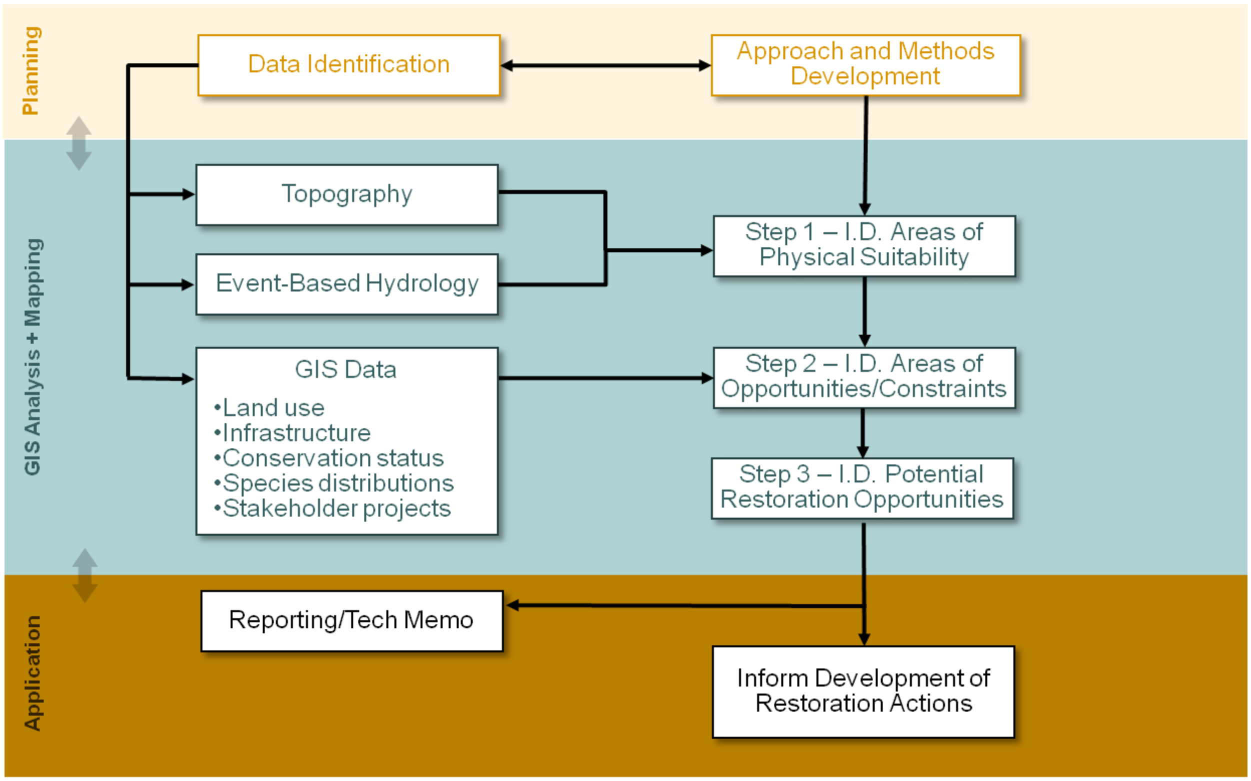

Figure 2-1. FROA Approach

2.2.1 Step 1: Identify Areas of Physical Suitability

To evaluate physical suitability for restoration actions, the FIP method was applied in a GIS analysis of corridors along the Sacramento and San Joaquin rivers and their major tributaries. This analysis was selected because of the importance of floodplain inundation for ecosystem functions, and because, at this planning level of investigation, the FIP method provided a relatively rapid approach for assessing floodplain inundation, as compared to the alternative use of more detailed hydraulic modeling. Furthermore, the pilot project application of the FIP method on the Feather River indicated its feasibility for application to the larger Sacramento and San Joaquin river systems.

The FIP analysis provides a spatial representation of floodplain inundation areas, and depths, relative to a varying water-surface profile. The FIP analysis "projects" a designated water-surface profile laterally from a stream centerline through levees or other obstructions out to a predetermined distance from a river centerline to provide an estimate of floodplain extent and depths if these obstructions were not present. It is acknowledged, however, that the actual water surface resulting from the removal of a levee or other obstruction would differ from that presented in the FIP analysis, but at this planning level the representation of potential floodplain inundation provided by the FIP analysis was deemed acceptable. The analysis was based on the results and conclusions of the pilot projects (Appendix A). It adapted concepts from the USACE HEC-EFM (USACE-HEC, 2009), the Frequently Activated Floodplain concept of Williams et al. (2009), and the HAR GIS tool of Dilts et al. (2010).

Several flows and associated water-surface profiles were evaluated using the FIP analysis, including:

- Water-surface profiles at the time of the CVFED (Central Valley Floodplain Evaluation and Delineation) Light Detection and Ranging (LiDAR) flights in March 2008 representing a low-water baseflow condition; termed the “Baseflow” FIP. Areas with Baseflow FIP would provide aquatic (riverine or lacustrine) habitats if hydrologically connected to a river.

- Seasonal flows and water-surface profiles derived using HEC-EFM representing a spring flow sustained for at least 7 days and occurring in 2 out of 3 years; termed the “67 percent chance Sustained Spring” FIP. Floodplains experiencing such sustained spring inundation would provide a variety of ecological functions, and greater aquatic foodweb productivity and fish utilization benefits than other floodplains (Williams et al. 2009).

- Peak flows and water-surface profiles associated with the 50 percent chance recurrence intervals; termed “50 percent chance” FIP. Floodplains inundated by these relatively frequent events would regularly sustain fluvial geomorphic processes (such as sediment scour and deposition) and provide inputs to the aquatic ecosystem (e.g., organic matter, including large woody material), among other functions, even where not experiencing sustained spring inundation.

- Peak flows and water-surface profiles associated with the 10 percent chance recurrence interval; termed the “10 percent chance” FIP. Floodplains inundated by these less-frequent events but not by 50 percent chance events would provide ecological functions similar to those inundated by more frequent events, but less frequently.

The analysis of FIP within the Systemwide Planning Area along the Sacramento and San Joaquin rivers and their major tributaries required topographic and hydraulic data. These data and the specific methods of the FIP analysis are described in the following sections.

Topographic Data

Accurate topographic data were required to evaluate FIP for these areas. AECOM completed an evaluation of readily available U.S. Geological Survey (USGS) 10-meter digital elevation models (DEM), and found that the data were not sufficiently detailed for this purpose.

The CVFED program recently mapped topography throughout the Central Valley, using LiDAR. AECOM received the raw LiDAR data files from the CVFED program in the fall of 2010. However, the raw data files were not usable for the Step 3 analysis, and creation of suitable files from the raw data (i.e., a digital terrain model) would duplicate work being completed by CVFED, which is not feasible from a cost or time standpoint.

As a solution to the lack of suitable topographic data, third-party software, Global Mapper, was used with the raw CVFED LiDAR data to create unprocessed digital terrain models. AECOM completed a test conversion of these digital terrain models to ArcGIS format, and found that the resultant topographic surface was usable for the FIP analysis, with minor modification and post-processing.

Hydraulic Data

For the various FIP analyses described above, hydraulic data were required to obtain water-surface profiles, with the exception of the Baseflow FIP analysis, which simply relied upon the water surfaces at the time of the CVFED LiDAR flight.

Hydraulic data for the 67 percent chance Sustained Spring FIP analysis were obtained from an analysis similar to the Feather River HEC-EFM/HEC-RAS pilot study; with a few differences that are noted and in Appendix A. Similar to the pilot study, HEC-EFM was used to query synthetic flow records for the Sacramento and San Joaquin river basins based on an ecosystem function relationship (EFR). The EFR included user-defined criteria such as a season, duration, and frequency. However, while the pilot study involved a HEC-EFM analysis of flow and stage time series produced by unsteady HEC-RAS modeling, findings from the study indicated this was not necessary and the remainder of the FROA effort simply used CalSim-derived synthetic flows that were queried directly by HEC-EFM. Comprehensive Study and Common Features HEC-RAS models were then used in a steady-flow analysis to model the flows identified by HEC-EFM, and the FIP tool was used to map the HEC-RAS water surface elevations (i.e., stages) at model cross-section locations. Major differences between the large-scale HEC-EFM/HEC-RAS analyses and the pilot-study analysis included:

1. Flow Estimation – CalSim-derived synthetic flows were queried directly by HEC-EFM after converting the Excel-based time series flow data to USACE-HEC's Data Storage System (HEC-DSS) format. For the pilot study, the flows were used as boundary conditions to an unsteady-flow HEC-RAS model developed by AECOM from the Comprehensive Study and Common Features models, and the flows and stage time series produced by unsteady HEC-RAS were queried using HEC-EFM. It was initially believed that using HEC-RAS would improve the estimate of flows and would also provide useful stage data. Following the pilot study however, it was agreed that this step was unnecessary and potentially misleading, as it could be perceived that using HEC-RAS unsteady flow provided an improvement in the estimate of flow rates. Because of the nature of the CalSim-derived flows, it was agreed that HEC-RAS would not provide any improvement in the estimate of flows (primarily because the flows were originally based on a monthly time step). In addition, the hydrographs produced by unsteady HEC-RAS for areas with strong backwater influence produced significant hysteresis (see HEC-EFM), resulting in large run-times for HEC-EFM and major errors in the resulting HEC-EFM rating curves. Lastly, because the EFR used in the final analysis did not require stage data, the CalSim-derived flows alone were sufficient for completing the HEC-EFM analysis. The consensus decision by the project team was that this approach provided reasonable results consistent with the level of detail provided by the CalSim-derived flows.

2. HEC-RAS Modeling – The Sacramento and San Joaquin river basins were modeled in HEC-RAS as a single basin-wide model (as opposed to subdividing the models into individual rivers). The flow rates selected by HEC-EFM were applied at the nearest river station and a steady-flow analysis was performed. The main purpose of modeling the entire basin as a single model was to provide consistent water surfaces at tributary confluences. A secondary benefit was that the Comprehensive Study and Common Features models were originally developed as basin-wide models and this reduced the level of effort required to subdivide the models. In addition, since the HEC-EFM analysis was performed using the CalSim-derived flows directly, individual Habitat Analysis Areas (HAA) were not needed (see Section 2.3.1 for an explanation of HAAs). Additional details regarding the HEC-RAS modeling include the following:

    a. Flow regimes were developed in HEC-EFM for each CalSim-derived node and for those hydrographs developed for tributaries not included in the CalSim-derived flow hydrographs. For the San Joaquin River, flow regimes were based on the restoration flows required by the San Joaquin River Restoration Settlement (as described in Reclamation, 2011). These flow regimes were developed by editing the HEC-EFM data file directly with a text-editor, as opposed to entering them individually in HEC-EFM. Also note that the stage data "required" by HEC-EFM is not necessary if stage results are not desired; thus, the flow hydrograph was used for both the flow and stage data source.

b. Where CalSim-derived flows were unavailable (e.g., Bear River, Yuba River, and Fresno Slough) flow hydrographs were developed by taking the difference between the upstream and downstream CalSim-derived hydrographs. This approach was used in the Lower Feather River Pilot Study and considered to be a reasonable estimate of the tributary flows. At confluences farther upstream on these tributaries (e.g., Union Pacific Interceptor Canal (UPIC), Dry Creek and Bear Creek (upstream from UPIC/Dry Creek)), the same approach could not be used and flows were not available; therefore, these areas were not mapped. For other areas where flows were unavailable, such as flood control bypasses and diversions and sloughs within the northern Sacramento-San Joaquin Delta (Delta), these areas were removed from the HEC-RAS models and not mapped.

c. The vertical datum of each model was not revised and was left in National Geodetic Vertical Datum of 1929 (NGVD 29). The stages output from the GIS extension to the HEC's River Analysis System (HEC-GeoRAS) and used during the FIP were adjusted to North American Vertical Datum 1988 (NAVD 88) using the same approach as was used for the conversion of the 50 percent and 10 percent chance stages.

d. The Sacramento and San Joaquin models were converted to HEC-RAS 4.1.0 to simplify the export of results to HEC-GeoRAS and ArcGIS.

e. The Sacramento River upstream from River Mile (RM) 143.24 was taken from the Sacramento Comprehensive Study model and added to the Sacramento River basin-wide Common Features model. The Common Features model did not include the Sacramento River upstream from RM 143.24. The Comprehensive Study river stations were revised to match the Common Features model by subtracting 0.8812 mile.

f. The Mean Tidal Level (MTL) at the Port Chicago tide gage was used for a constant downstream stage boundary condition for the Sacramento and San Joaquin rivers. This approach was discussed by the project team and considered reasonable. Tidal data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (NOAA, 2011). The gage's MTL datum and NAVD datum values and the NGVD-to-NAVD conversion factor were applied, as follows:

   MTL(NGVD) = (MTL – NAVD) – (NAVD NGVD Conversion Factor)

   MTL(NGVD) = (6.56 – 2.89) – (2.613205)

   MTL(NGVD) = 1.0558 feet

g. The existing HEC-RAS model cross sections were not updated because the official DWR review of the new CVFED Task Order 20 LiDAR-derived DEMs was not complete at the time of this work.

h. Additional consideration was given to whether alternative analyses of sustained spring flows should be performed using either a higher/lower frequency, extended duration, or different season. It was agreed that the 67 percent chance relationship used for this study was the best suited to identifying potential habitat areas and was consistent with past work by others.

Hydraulic data (flows and stages) for the 50 percent chance and 10 percent chance recurrence interval FIP analyses were derived directly from the Comprehensive Study UNET models. Each pair of flow and stage values represents a discrete reach within the Sacramento and San Joaquin river systems.

An important point to clarify is the difference between the 50 percent chance and 10 percent chance recurrence interval FIP analyses versus the 67 percent chance Sustained Spring FIP analysis. The 50 percent chance and 10 percent chance water-surface profile elevations (stages) used for the FIP analysis correspond to peak flow conditions derived from a statistical flood frequency analysis of a series of maximum annual flows. The stages developed for the 67 percent chance Sustained Spring FIP analysis, while corresponding to a 67 percent chance frequency, are limited to those events that occur between March 15 and May 15 and for no less than 7 days. As a result, the 67 percent chance Sustained Spring events are significantly smaller flow events than the 50 percent chance and 10 percent chance events and may correspond to non-storm conditions. For example, 67 percent chance Sustained Spring FIP on the lower American River and Sacramento River downstream from the American River correspond to flows of approximately 2,900 to 3,100 cubic feet per second (cfs) and 21,000 cfs, respectively, which are less than mean monthly winter flows. The 67 percent chance Sustained Spring FIP analysis primarily identifies potential habitat during spring (e.g., salmonid rearing habitat), while the 50 percent chance and 10 percent chance provides information about more general inundated floodplain habitat attributes.

FIP Analysis

The FIP analysis methodology established during the Feather River pilot study was applied to the remainder of the Sacramento and San Joaquin river systems. All aspects of this approach remained the same except that the CVFED pre-processed LiDAR and breakline data, which were used in the pilot study, were not available for the remainder of the Systemwide Planning Area study area. Therefore, the analysis used the unprocessed digital terrain models developed with the Global Mapper software.

Based on the results of this analysis, in combination with the data regarding opportunities and constraints described in Section 2.4.2 below, reaches were identified with greater and/or more extensive potential opportunities for restoration, as described below in Section 2.4.3.

2.2.2 Step 2: Identify Opportunities and Constraints

The identification of other opportunities and constraints besides physical suitability relied on readily available geospatial data layers, except for information on the location of existing interest in restoration, which was compiled from stakeholders for this analysis.

As part of the CVFPP planning process, existing datasets potentially of use in development of the CVFPP and related documents and appendices were reviewed (AECOM, 2010a). The intent of this review was to document those readily available and public-domain geospatial datasets that would be used for the CVFPP, subject to a defined set of selection rules. Included among these rules were the following:

- Data had to be freely available on the Internet or available from a CVFPP participant (i.e., DWR, MWH, or AECOM).

- Data had to cover the entirety of the study area, or as much of the area as possible.

- Where a choice between data currency and data detail (i.e., spatial resolution) was available, more current data were preferred over more detailed data unless it was felt that enhanced data resolution (either spatial or attribute) was essential.

Data collected to help identify areas with opportunities and/or constraints, subject to these rules, are described below.

- **Agricultural and Natural Land Use/Land Cover** – Land use/land cover data were compiled for Important Farmland (as defined by DOC, 2011) from the California Department of Conservation's Farmland Mapping and Monitoring Program (DOC, 2008) and wetlands and riparian vegetation (DWR, 2012).

- **Urban Areas** – These data were developed by DWR (2010a) using data provided by the California Department of Conservation's Farmland Mapping and Monitoring Program.

- **Major Infrastructure** – Major infrastructure consisted of data showing the locations of major roads and highways (U.S. Census Bureau, 2007), railways (Caltrans, 2009), and levees and levee condition (developed by DWR during the CVFPP planning process, and under development by DWR's Urban and Non-Urban Levee Evaluation projects).

- **Terrestrial Sensitive Species Occurrences** – Occurrences of terrestrial sensitive species, meaning species considered to be threatened, endangered, rare, fully protected, or species with similar status that are tracked by the California Department of Fish and Game (DFG) in the California Natural Diversity Database (CNDDB). The January 2011 version of the database (DFG, 2011) was used for this analysis.

- **Salmonid Spawning Reaches** – Reaches of rivers known to support spawning of fall-late-fall-run, winter-run, and spring-run Chinook salmon (*Oncorhynchus tshawytscha*), as well as Central Valley steelhead (*Oncorhynchus mykiss)*, were mapped from the CalFish abundance database (DFG, 2005).

- **Conservation Status** – Locations of preserved and protected habitat were based on the California protected areas database (GreenInfo Network, 2010).

Because of the nature of these data and known data gaps, limitations, or inaccuracies, these data were not considered to conclusively indicate areas that would be more suitable for ecological restoration relative to other areas. For example, the CNDDB only records positive sightings of species based on field surveys. It does not document the actual distribution of species, because additional populations of species tracked by CNDDB may be found in areas that have not been surveyed. This does not indicate that these data have no value in identifying potential ecosystem restoration opportunities, but it does underscore the inherent limitations of these data for use in evaluations of potential ecosystem restoration sites, particularly without considering the physical suitability of potential sites and other applicable data.

In addition to these selected geospatial datasets, information on existing interest in restoring particular areas was compiled from stakeholders. Focused outreach was conducted throughout the study area to document potential ecosystem restoration projects previously identified by various CVFPP stakeholders. Meetings were held with the stakeholder groups listed below.

- The Nature Conservancy (Northern Central Valley, California Water Program, San Joaquin Valley Project)
- American Rivers
- DWR Northern Regional Office
- DWR South Central Regional Office
- River Partners
- San Joaquin River Conservancy
- DFG (Central Region)
- U.S. Department of the Interior, Bureau of Reclamation (SJRRP)
- San Joaquin River Parkway and Conservation Trust
- Natural Resources Defense Council
- NewFields River Basin Services, LLC
- ESA PWA, Inc.

Owing to time constraints, not all potential ecosystem restoration stakeholders in the study area were interviewed.

Each interview consisted of a facilitated discussion, lead by DWR staff, to solicit stakeholder input on previously identified ecosystem restoration projects. Specific information provided by stakeholders regarding their planned projects has been treated as confidential. For each identified project, stakeholders were asked to provide the following information:

- Location of the potential project site, along with geospatial data depicting the project footprint, if available
- Project purpose, including ecosystem functions targeted for restoration
- Specific restoration activities proposed for the project, including a formal restoration plan, if available
- Current biological and physical conditions on the site, including an existing conditions report, if available
- Name and contact information for the project proponent
- Funding sources for the project
- Sources of the information described above

In addition to stakeholder interviews, existing reports that identified potential ecosystem restoration opportunities were also reviewed. These included the Sutter Basin Feasibility Study (USACE, 2010) and the Final Database of Potential Multi-Objective Flood Damage Reduction Actions (CBDA, 2004). Projects located within the study area and that would provide ecosystem benefits were included with the group of stakeholder-identified projects.

As previously described, these areas will be considered as potential restoration opportunities in the identification of reaches to be analyzed in more detail.

2.2.3 Step 3: Evaluate Potential for Restoration

The potential for restoration was determined by evaluating relationships among physically suitable areas and the locations of opportunities and constraints. This evaluation was based on the review and combination of geospatial data layers with ESRI’s ArcGIS software. Through it, reaches with greater and/or more extensive potential opportunities for restoration were identified.

The Sacramento and San Joaquin river systems were subdivided into 29 reaches. Boundaries between reaches were located at discontinuities in river or floodplain morphology, and/or to major junctions with tributaries, bypasses, or canals. In the upper Sacramento and San Joaquin river basins, reaches correspond to those established by the Sacramento River Conservation Area Forum and the SJRRP, respectively.

For each reach, four combinations of physically suitable conditions and suitable land use/land cover representing different restoration opportunities were mapped and their acreages tabulated:

- Nonurban floodplain with 67 percent chance Sustained Spring Flow or 50 percent chance FIP hydrologically connected to the river with riparian vegetation

- Nonurban floodplain with 67 percent chance Sustained Spring Flow or 50 percent chance FIP hydrologically connected to the river without riparian vegetation

- Nonurban floodplain with 67 percent chance Sustained Spring Flow FIP hydrologically disconnected from the river

- Nonurban floodplain with 50 percent chance FIP hydrologically disconnected from the river

Additional information regarding the location and extent of opportunities and constraints was also compiled for each reach.

3.0 Results of Floodplain Restoration Opportunities Analysis

For river reaches and bypasses included in the FROA, results are summarized in narrative descriptions, tables, and maps. FROA includes the Sacramento River from Woodson Bridge State Recreation Area to Collinsville, the San Joaquin River from Friant Dam to Stockton, the lower Feather River, and the lowermost reaches of other major tributaries of the Sacramento and San Joaquin rivers (i.e., the Bear, Yuba, American, Stanislaus, Tuolumne, and Merced rivers). It does not include smaller tributaries. The Sutter and Yolo bypasses are also included.

Narrative descriptions of reaches are provided in Sections 3.1 through 3.5. Maps and tables are provided in Section 3.6. Maps and tables are provided in a separate section to facilitate ease of use, particularly for comparisons of multiple maps.

In the reach descriptions, information is provided for the approximately 2-mile-wide corridors modeled along each river (with the exception of the Yolo Bypass where a 14,000-foot-wide corridor was modeled to account for levees that are set more than 2 miles apart). This information includes physical conditions (FIP and hydrologic connectivity), land use/land cover, infrastructure, conservation status, and occurrences of sensitive species.

Information in the narrative descriptions was primarily derived from the data sources displayed on the maps in this chapter, and previously described in Section 2.4. In addition, some supporting information from the following sources was also incorporated:

- Status and Trends of the Riparian and Riverine Ecosystems of the Systemwide Planning Area (DWR, 2011);
- State Plan of Flood Control Descriptive Document (DWR, 2010b);
- California Natural Diversity Database (DFG, 2011);

- Sacramento River Conservation Area Forum Handbook (Sacramento River Conservation Area Forum, 2003); and
- Draft Program Environmental Impact Statement/Environmental Impact Report San Joaquin River Restoration Program (Reclamation, 2011).

Several terms are used repeatedly in describing the reaches. “Corridor” refers to the extent of the modeled area, which generally extends approximately 1 mile from the river’s centerline. “Connected” and “disconnected” refer to hydrologic connection to the river during a 50 percent chance event (i.e., connected areas would be inundated during a 50 percent chance event). Also, throughout this text, 67 percent chance Sustained Spring FIP refers to a floodplain area 1 foot or more above the water surface of a 67 percent chance spring flow sustained for at least 7 days, but at a lower elevation than the 50 percent chance water surface. Similarly, 50 percent chance FIP refers to floodplain areas 1 foot or more above the 50 percent chance water surface and below the water surface of the 10 percent chance flow. As described in Section 2.2.9, the process used to estimate water surface elevations resulted in elevations that varied within 1 foot of true elevations. Figure 3-1 illustrates the relationship between these different water surfaces and the elevation zones corresponding to areas with a different FIP.

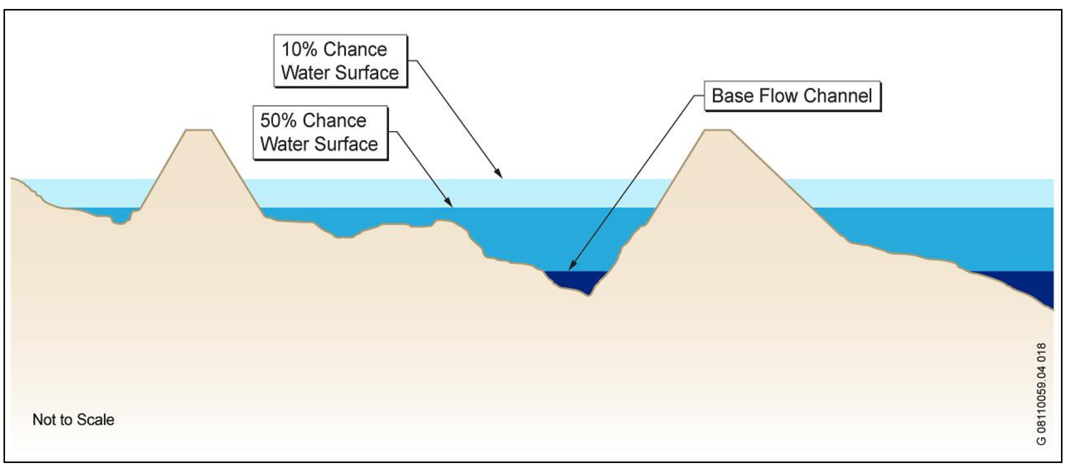

Figure 3-1. Hypothetical Cross Section with Boundary Water Surfaces of FIP Categories

3.1 Sacramento River Reach Descriptions

3.1.1 Woodson Bridge State Recreation Area to Chico Landing

From Woodson Bridge State Recreation Area (SRA) to Chico Landing, the Sacramento River actively meanders through the valley floor along much of this reach. (The majority of the banks along this reach are natural (i.e., without revetment) (DWR, 2011).) The active channel is fairly wide in some stretches and the river splits into multiple forks at many different locations, creating gravel islands, often with riparian vegetation. Historic bends in the river are visible throughout this reach and are remainders of historical channel locations with the riparian corridor and oxbow lakes still present in many locations.

In this reach, the corridor along the river is relatively evenly distributed among areas with 50 percent chance, 10 percent chance, and greater than 10 percent chance FIP. Most areas with 50 percent chance FIP are connected to the river. Only a small percentage of the floodplain has Below Baseflow FIP, and there are almost no areas with 67 percent chance Sustained Spring FIP.

Nearly 25 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas include portions of the Sacramento River National Wildlife Refuge, Sacramento River Wildlife Area, Butte Sink Wildlife Management Area, and Bidwell-Sacramento River State Park; the Woodson Bridge SRA; Merrill's Landing Wildlife Area; Westermann, Brattan, Kaplan, and Verschagin preserves; and Bureau of Land Management-managed land.

Natural vegetation covers one-third of the corridor along this reach, and riparian/wetland vegetation approximately an eighth of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sacramento anthicid beetle (*Anthicus sacramento*), Valley elderberry longhorn beetle (VELB) (*Desmocerus californicus dimorphus*), Swainson's hawk (*Buteo swainsoni*), colonies of bank swallow (*Riparia riparia*), yellow-billed cuckoo (*Coccyzus americanus*), western red bat (*Lasiurus blossevilli*), and western mastiff bat (*Eumops perotis*). This reach also provides habitat for several sensitive fish: foraging adult green sturgeon (*Acipenser medirostris*); migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Developed land uses occupy only a very small portion of the corridor along this reach (less than 2 percent), primarily in the vicinity of Hamilton City.

Other than levees, there is very little major infrastructure along this reach of the Sacramento River except between RM 196 and 197, where State Route (SR) 32, a natural gas pipeline, and an electrical transmission line cross the river.

Along this reach, several nonproject levees (i.e., levees that are not part of the SPFC) protect portions of both banks. This reach does not have project levees.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.2 Chico Landing to Colusa

From Chico Landing to Colusa, the Sacramento River actively meanders through the valley floor, actively eroding banks, producing oxbows and meander scrolls on the floodplain along much of this reach. (The majority of the banks along this reach are natural (i.e., without revetment) (DWR, 2011).) In this reach, it also historically overflowed into floodbasins. Currently, during flood flows, water from the Sacramento River enters the Butte Basin at the 3Bs natural overflow, the M&T and Goose Lake flood relief structures, and at Moulton and Colusa weirs.

In this reach, more than two-thirds of the corridor along the river has 50 percent chance FIP, and more than half of this area is connected to the river. Only a very small area has 67 percent chance Sustained Spring FIP.

Natural vegetation covers more than one-third of the corridor along this reach, and riparian/wetland vegetation approximately an eighth of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow (*Hibiscus lasiocarpus* var. *occidentalis*), several beetles (Antioch Dunes anthicid beetle (*Anthicus antiochensis*), Sacramento anthicid beetle, Sacramento Valley tiger beetle (*Cicindela hirticollis abrupta*), VELB), giant garter snake (*Thamniopsis gigas*), colonies of bank swallow, Swainson's hawk, colonies of tricolored blackbirds (*Agelaius tricolor*), yellow-billed cuckoo, western mastiff bat, and western red bat. This reach also provides habitat for several sensitive fish including foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include portions of the Sacramento River National Wildlife Refuge, Bidwell-Sacramento River State Park, Sacramento River Wildlife Area, and Butte Sink Wildlife

Management Area; the Colusa Bypass Wildlife Area; and the Hartley Island, Jensen, and Cannell preserves.

Developed land uses occupy only a small portion of the corridor along this reach (only about 1 percent), primarily at Colusa. Other than levees, there is little major infrastructure along this reach of the Sacramento River. Natural gas pipelines cross near RMs 184, 174, and 162. SR 162 crosses the river near RM 166, and natural gas pipelines and electrical transmission lines are along the river corridor at several hundred to several thousand feet from the river.

At Ord Ferry on the west bank and 7.5 miles downstream from Ord Ferry on the east bank, SPFC levees border the river downstream along this reach, but are often as far as 1 mile apart. The physical condition of these levees is of medium concern, except for a 10- to 12-mile-long stretch upstream from Colusa where levee physical condition is of higher concern. Upstream from these SPFC levees are several nonproject levees on portions of the reach.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.3 Colusa to Verona

The general character of the Sacramento River changes downstream from Colusa from a dynamic and active meandering channel to a confined, narrow channel generally restricted from migration along the majority of its length. (DWR, 2011). While levees exist along portions of the river upstream from Colusa, levees are located much closer to the river edge as the river continues south to the Delta. The channel width is fairly uniform and river bends are static as a result of confinement by levees.

From Colusa to Verona, more than half of the corridor along the river has 50 percent chance FIP, but only a small portion of this area remains connected to the river. There also are large areas with Below Base Flow FIP. Most of these areas represent historical floodbasins that are disconnected from the river. Along this reach, about 10 percent of evaluated floodplain has a 67 percent chance Sustained Spring FIP, almost all of which is disconnected from the river.

Natural vegetation covers approximately one-eighth of the corridor along this reach, and riparian/wetland vegetation covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, Sacramento tiger beetle, VELB, giant garter snake, colonies of bank swallows, Swainson’s hawk, colonies of tricolored blackbirds, yellow-billed cuckoo, and western red bat. This reach also provides habitat for several sensitive fish, including Sacramento splittail (*pogonichthys macrolepidotus*), foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Along this reach of the Sacramento River, very little of the land has been conserved (about 1 percent of the corridor). Conserved areas along this reach of the Sacramento River include the Rohleder Preserve, Collins Eddy Wildlife Area, and the Fremont Weir Wildlife Area.

Developed land uses occupy only a small portion of the corridor along this reach (only about 2 percent), primarily in the vicinity of Colusa. However, there is more major infrastructure along this reach of the Sacramento River than along upstream reaches. The Colusa Highway crosses the river between RMs 134 and 133, and SR 113 crosses near RM 90. Natural gas pipelines cross the river near RMs 140, 127, 126; and electrical transmission lines cross the river near RMs 134, 121, 92, 86, and 80. Also, major roads, natural gas pipelines, and electrical transmission lines are located within 1 mile of the river at a number of locations.

There are SPFC levees along both river banks in this reach. The physical condition of these levees is of higher concern, except for several miles of levee east of the river downstream from Colusa.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.4 Verona to American River

From Verona to the American River, about two-thirds of the corridor along the river has 50 percent chance FIP and about a quarter has 67 percent chance Sustained Spring FIP. Almost all of this floodplain is disconnected from the river.

Natural vegetation covers more than 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, VELB, giant garter snake, western pond turtle, rookeries of wading birds, colonies of tricolored blackbird, and Swainson’s hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Less than 10 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include Elkhorn Regional County Park, Sacramento Bypass Wildlife Area, several Natomas Basin Conservancy reserves, and Discovery Park at the downstream end of the American River Parkway.

Developed land uses only occupy about 15 percent of the corridor along this reach. However, at the southern end of this reach, where the river enters Sacramento and West Sacramento, developed land uses occupy most of the 2-mile-wide corridor. Along this reach of the Sacramento River, Interstate (I)-5 crosses the river near RM 71 and crosses the American River at its junction with the Sacramento, and I-80 crosses the river near RM 63. Natural gas pipelines cross near RMs 67 and 64, and an electrical transmission line crosses near RM 63. In addition to major infrastructure facilities crossing the river, the Sacramento International Airport is within 2 miles of this reach of the river, and consequently is an important constraint on the restoration of habitat.

There are SPFC levees along both banks. The physical condition of these levees varies from lower concern where sections of the Natomas levees have recently been improved and medium concern for approximately 3.5 miles of the west levee south of the I-5 crossing, to higher concern elsewhere.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.5 American River to Freeport

From the American River to Freeport, about 20 percent of the corridor along the river has Below Baseflow FIP, nearly 30 percent has 67 percent chance Sustained Spring FIP, and more than 40 percent has 50 percent chance FIP. This FIP distribution reflects the varied landforms along this reach that include historical floodbasins and natural levees along the river channel. Almost all of this floodplain is disconnected from the river. In this tidally influenced reach, the Sacramento River enters the legal Delta.

Natural vegetation covers nearly 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 1 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford’s arrowhead (*Sagittaria sanfordii*), VELB, and Swainson’s hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon;

and this reach contains delta smelt (*Hypomesus transpacificus*)-designated critical habitat.

Along this reach of the Sacramento River, only a small amount of land has been conserved (less than 5 percent of the corridor). Conserved areas along this reach are limited to smaller city and county parks and several other public-owned parcels.

Developed land uses occupy nearly two-thirds of the floodplain along this reach. Because this reach of the Sacramento River passes through the city of Sacramento, the corridor along the river has a high density of infrastructure, particularly from RMs 60 to 57. In addition to multiple major road, pipeline, and transmission line crossings, there are a number of Cortese sites (which have hazardous materials issues) and refineries. In addition, Sacramento Executive Airport is within 2 miles of this reach of the river.

There are SPFC levees along both banks of the river. The physical condition of these levees is generally of higher concern, but the physical condition of several sections of the west levee is of lower concern.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.6 Freeport to Delta Cross Channel

From Freeport to the Delta Cross Channel, approximately 60 percent of the corridor along the river has a Below Baseflow FIP, and of the remainder, most has a 67 percent chance Sustained Spring FIP. This FIP distribution reflects both historical landforms, and historical and ongoing changes to landforms (e.g., subsidence of areas with drained, organic soils). Almost all of this floodplain is isolated from the river. This Delta reach of the Sacramento River is tidally influenced.

Natural vegetation covers nearly 20 percent of the corridor along this reach, and riparian/wetland vegetation covers about 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, Sanford’s arrowhead, several plants characteristic of sloughs and tidal marshes (e.g., Suisun Marsh aster (*Symphyotrichum lentum*), Delta tule pea (*Lathyrus jepsonii*), and Mason’s lilaeopsis (*Lilaeopsis masonii*)) VELB, giant garter snake, western pond turtle (*Emys marmorata*), wading bird rookeries, white-tailed kite (*Elanus leucurus*), and Swainson’s hawk, among others. This reach also provides habitat for several sensitive fish, including Sacramento splittail, delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Less than 10 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved lands include sanitation district and county open space land, Delta Meadows State Park, and a portion of Stone Lakes National Wildlife Refuge.

Along this reach, there are small areas of developed land uses at Cortland and near Walnut Grove, but developed land uses only occupy several percent of the corridor along this reach. Besides levees, there is little major infrastructure along this reach. SR 160 runs along the east bank of the river, and an electrical transmission line crosses the river between RMs 31 and 32.

SPFC levees are along both river banks. In the upstream half of this reach, the physical condition of the levees is generally of higher concern, but in the downstream half of this reach, their physical condition is generally of medium concern.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.7 Delta Cross Channel to Deep Water Ship Channel

From the Delta Cross Channel to the Deep Water Ship Channel, almost all of the corridor along the river has a Below Baseflow FIP, and is disconnected from the river. This floodplain consists of Delta islands bordered by sloughs, and that have been leveed and drained, and are in agricultural use. Consequently, the organic soils of these islands have been oxidizing and the land surface subsiding. There are only a few hundred acres along this reach with either 67 percent chance Sustained Spring FIP or 50 percent chance FIP, most of which is connected to the river. This Delta reach of the Sacramento River is tidally influenced.

Natural vegetation covers more than 10 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, several plants characteristic of sloughs and tidal marshes, Sacramento anthicid beetle, VELB, western pond turtle, Swainson’s hawk, and western red bat. This reach also provides habitat for several sensitive fish: delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Very little of the corridor along this reach of the Sacramento River has been conserved (less than 2 percent of the corridor). Conserved land along this reach is limited to a small area of state land near RM 15.

Along this reach there are small areas of developed land uses at Walnut Grove and Isleton, but developed land uses only account for several percent of the corridor along this reach. SR 160 runs along the river bank, and other major infrastructure includes an electrical transmission line that crosses the river near RM 17, and natural gas pipelines that cross the river near RMs 21, 20, and 15.

SPFC levees are along both river banks. The physical condition of the west levee is of medium concern; the physical condition of the west levee is of medium concern from the Delta Cross Channel to approximately RM 20, and of higher concern from near RM 20 to the junction with the Deep Water Ship Channel.

Stakeholders identified potential restoration opportunities along this reach of the Sacramento River.

3.1.8 Deep Water Ship Channel to Collinsville

From the Deep Water Ship Channel to Collinsville, the corridor along the river consists of Delta islands with a Below Base Flow FIP but disconnected from the river, and an area of uplands downstream from Rio Vista. There are only a few hundred acres along this reach with either 67 percent chance Sustained Spring FIP or 50 percent chance FIP, most of which is disconnected from the river. This Delta reach of the Sacramento River is strongly tidally influenced.

Natural vegetation covers more than two-thirds of the corridor along this reach, but riparian/wetland vegetation only covers about 1 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, several plants characteristic of sloughs and tidal marshes, Antioch Dunes and Sacramento anthicid beetles, VELB, giant garter snake, Swainson’s hawk, and western red bat. This reach also provides habitat for several sensitive fish, including delta smelt; foraging adult green sturgeon; migrating, holding, and rearing steelhead and winter- and fall-/late-fall-run Chinook salmon; and migrating and rearing spring-run Chinook salmon.

Approximately 5 percent of the corridor along this reach of the Sacramento River has been conserved. Conserved areas along this reach include Brannan Island SRA, Decker Island Wildlife Area, and Lower Sherman Island Wildlife Area.

A small portion of this reach has developed land uses at Rio Vista. In addition to levees, this reach has a high density of other major infrastructure. At Rio Vista, SR 12 crosses the river, as do two natural gas pipelines, and the Rio Vista Municipal Airport is within 1 mile of the river. Also, near the downstream end of this reach, from approximately RMs 7 to 4, nine natural gas pipelines and electrical transmission lines cross the river.

SPFC levees are on the east river bank for the entire length of the reach and on the west bank at RMs 13 to 14 (near Rio Vista). The physical condition of these levees is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Sacramento River.

3.2 Sacramento River Tributary Reach Descriptions

The lowermost reaches of the Feather, Yuba, Bear, and American rivers were evaluated. These reaches begin approximately 1 mile upstream from the tributary's junction with the Sacramento River because the corridor along the Sacramento River extends 1 mile from the centerline of the Sacramento River.

3.2.1 Feather River – Thermalito Afterbay to Yuba River

Along the Feather River from Thermolito Afterbay to the Yuba River, the floodplain has almost no areas with 67 percent chance Sustained Spring FIP. Areas with 50 percent chance FIP, however, account for more than 40 percent of the corridor along the river, with the remainder evenly divided between 10 percent chance and greater than 10 percent chance FIP. More than two-thirds of areas with 50 percent chance FIP are connected to the river. A series of remnant gravel pit pools/ponds connect to the main channel in this reach. (Connected gravel pits can affect flows and water temperatures, disrupt sediment transport, and provide habitat for nonnative fish that compete with and prey on native species.)

Natural vegetation covers about one-quarter of the corridor along this reach, and riparian/wetland vegetation covers nearly 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, colonies of bank swallows, western yellow-billed cuckoo, and Swainson's hawk. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; migrating, holding, spawning, and rearing fall-run

Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

More than 10 percent of the corridor along this reach of the Feather River has been conserved. Unlike most other reaches, the majority of conserved area is disconnected from the river. Conserved areas in this reach include the Oroville Wildlife Area and a portion of the Feather River Wildlife Area.

Less than 10 percent of the corridor along this reach has developed land uses, and most of this reach has only small amounts of developed land uses and major infrastructure: three gravel mines are near RMs 58 and 55 to 56, and a low, notched rock dam spans the river near RM 39. However, Yuba City and Marysville are at the downstream end of this reach, and along the river, developed land uses are extensive from about RM 31 to the end of the reach at RM 27. A number of pipelines, roads, and electrical transmission lines cross the river in this area. Also, there is a community airport at Yuba City within 1 mile of the river.

SPFC facilities in this reach include a levee throughout the reach on the west bank, the Sutter-Butte Canal Headgate, a levee extending downstream from Honcutt Creek on the east side of the river, and a ring levee around Marysville. The physical condition of these levees is of higher concern. There are also several nonproject levees.

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.2 Feather River – Yuba River to Bear River

Between the Yuba and Bear rivers, most of the corridor along the Feather River has 50 percent chance FIP. More than two-thirds of these areas are disconnected from the river.

Natural vegetation covers nearly one-third of the corridor along this reach, and riparian/wetland vegetation covers approximately 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, colonies of bank swallows, and Swainson’s hawk. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Feather River has been conserved. A portion of the Feather River Wildlife Area is along this reach.

Developed land uses occupy about 10 percent of the corridor along this reach. The Yuba City and Marysville areas extend along the upstream end of this reach (RMs 24 to 27), and developed land uses are extensive in these areas, an electrical transmission line and a natural gas pipeline cross the river, and a power plant is adjacent to the river. Also, both the Yuba City and Yuba County airports are within 2 miles of the river. However, downstream from the Yuba City and Marysville areas, there is little developed land or major infrastructure except for an electrical transmission line that crosses the river near RM 23 and levees that extend along both banks.

SPFC levees are on both sides of the river and are spaced from about 0.5- to 1-mile apart. The physical condition of most of the west levee is of higher concern; the physical condition of the east bank levee is of lower concern.

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.3 Feather River – Bear River to Sutter Bypass

From the Bear River to the Sutter Bypass, most of the corridor along the Feather River has 50 percent chance FIP. About two-thirds of these areas are disconnected from the river.

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers approximately 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Antioch Dunes and Sacramento anthicid beetles, VELB, giant garter snake, western pond turtle, colonies of bank swallows, western yellow-billed cuckoo, and Swainson’s hawk. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Feather River has been conserved. A portion of the Feather River Wildlife Area is along this reach.

This reach has only a small amount of developed land (less than 2 percent of the corridor), primarily near Nicolaus (near RM 10). SR 99 crosses the river near RM 9, and electrical transmission lines cross the river near RMs 9 and 10.

SPFC levees are on both banks along this reach. The physical condition of these levees is of higher concern except for approximately 2 miles of the north levee (from RM 10 to the junction with the Sutter Bypass).

Stakeholders identified potential restoration opportunities along this reach of the Feather River.

3.2.4 Feather River – Sutter Bypass to Sacramento River

Similar to upstream reaches, from the Sutter Bypass to the Sacramento River, most of the corridor along the Feather River has 50 percent chance FIP. However, this reach has more areas with 67 percent chance Sustained Spring FIP than upstream reaches (12 percent versus 1 percent or less). Connectivity of these areas to the river is also greater along upstream reaches. In this reach, the Feather River has a relatively straight channel located along the eastern edge of the floodway.

Natural vegetation covers more than 20 percent of the corridor along this reach, but riparian/wetland vegetation only covers several percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sacramento Valley tiger beetle, giant garter snake, colonies of bank swallows and tricolored blackbirds, and Swainson’s hawk. Along this reach of the Feather River, there are no conserved areas. This reach also provides habitat for several sensitive fish, including Sacramento splittail, foraging adult green sturgeon; migrating, holding, and rearing fall-run Chinook salmon; migrating, holding, and rearing steelhead; and migrating and rearing spring-run Chinook salmon.

This reach has only a small amount of developed land (less than 2 percent of the corridor), and no major infrastructure crosses the river, although an electrical transmission line is located near the east riverbank, where the Garden Highway also is located adjacent to the levee.

SPFC levees are on both river banks along this reach. The physical condition of these levees is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Feather River.

3.2.5 Yuba River

The lower reach of the Yuba River is a relatively narrow floodplain constrained by nearby terraces and other uplands. Consequently, more than half of the corridor along the river has a greater than 10 percent chance FIP. More than 10 percent of the floodplain corridor had 50 percent chance FIP, about half of which is connected to the river. Very little floodplain had 67 percent chance Sustained Spring FIP. South of the river, a portion of the Yuba Goldfields is within the corridor. This extensive disturbed area contains numerous small water features and patches of riparian vegetation.

Natural vegetation covers approximately 60 percent of the corridor along this reach, but riparian/wetland vegetation only covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, western pond turtle, California black rail (*Laterallus jamaicensis coturniculus*), colonies of tricolored black birds, and Swainson’s hawk. This reach also provides habitat for several sensitive fish, including migrating, holding, and rearing steelhead and fall-run Chinook; and migrating and rearing spring-run Chinook.

Approximately 7 percent of the corridor along this reach has been conserved. Conserved areas along this reach of the Yuba River are limited to several Bureau of Land Management-managed parcels (mostly upstream from RM 10) and City of Marysville open space approximately 1 mile upstream from the junction with the Feather River.

Developed land uses occupy less than 10 percent of the corridor along this reach. However, Marysville is at the downstream end of this reach where developed land uses are extensive. Upstream from Marysville, there is little developed land or major infrastructure. From about RM 8 to RM 10 there are two gravel mines and two electrical transmission lines that cross the river, and further upstream is Daguerre Point Dam.

SPFC levees are widely spaced on both sides of the river. There is also a nonproject levee around RMs 6 to 8. The physical condition of segments of these levees varies from lower to higher concern.

Stakeholders identified potential restoration opportunities along this reach of the Yuba River.

3.2.6 Bear River

Along the lowest reach of the Bear River, almost half of the corridor along the river had 67 percent chance Sustained Spring FIP or 50 percent chance FIP. Most of this area (85 percent or more) is disconnected from the river.

Natural vegetation covers nearly one-third of the corridor along this reach, and riparian/wetland vegetation covers several percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, giant garter snake, western pond turtle, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing steelhead; and opportunistic/intermittent migrating, holding, spawning, and rearing for fall-run Chinook salmon.

Only a very small portion of the corridor along this reach of the Bear River has been conserved (approximately 1 percent of the corridor). Conserved areas along this reach are limited to several water district-owned parcels.

Developed land uses occupy less than 5 percent of the corridor along this reach, and are concentrated near Wheatland (near RMs 9 to 11). Major infrastructure includes river crossings by SRs 65 and 70 (near RMs 4 and 10, respectively), and crossings by electrical transmission lines and natural gas pipelines near those major road crossings.

There are SPFC levees on both banks for approximately the first 7 miles of this reach, and the south bank levee continues along Dry Creek. The physical condition of the north levee is of lower concern; the physical condition of the south levee is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the Bear River.

3.2.7 American River

Along the lowest reach of the American River, only about 1 percent of the corridor along the river has 67 percent chance Sustained Spring FIP, and only 14 percent has 50 percent chance FIP. Most of these areas are connected to the river.

Natural vegetation covers more than 20 percent of the corridor along this reach, and riparian/wetland vegetation covers about 8 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead, VELB, western pond turtle, wading bird rookeries, colonies of bank swallows, white-tailed kite, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing steelhead; and migrating, holding, spawning, and rearing fall-run Chinook salmon.

More than 20 percent of the corridor along this reach of the American River has been conserved. This reach has the largest percentage of conserved area among reaches of the Sacramento and San Joaquin river systems. Conserved areas along this reach of the American River include the American River Parkway and associated county parks.

Because this reach passes through the Sacramento Metropolitan Area, developed land uses occupy more than three-quarters of the land along this reach. There also is a high density of major infrastructure along the river, particularly from RMs 0 to 9. Multiple major roads and railroads, natural gas pipelines, and electrical transmission lines cross the river.

SPFC levees are on both sides of the river for the first 10 miles of this reach and extend further along the north side. The physical condition of these levees is of lower concern, except for the section of the north levee between the river and the Natomas Basin, whose physical condition is of higher concern.

Stakeholders did not identify potential restoration opportunities along this reach of the American River.

3.3 Sutter and Yolo Bypass Descriptions

3.3.1 Sutter Bypass

The Sutter Bypass is a wide flood channel that carries floodwater diverted from the Sacramento River at several weirs north of the Sutter Buttes to the confluence of the Feather and Sacramento rivers, and then on to the Yolo Bypass. From the west, Butte Creek (Butte Slough) enters the bypass. It is inundated in most years by water diverted out of the Sacramento River.

The Sutter Bypass is used mainly for agriculture, and there are only small amounts of natural vegetation. Riparian and wetland-associated sensitive species documented along this reach include woolly rose-mallow, giant garter snake, western pond turtle, California black rail, yellow-headed blackbird (*Xanthocephalus xanthocephalus*), colonies of tricolored blackbirds, and Swainson’s hawk. Sutter National Wildlife Refuge extends throughout this reach of the Sutter Bypass. The Sutter Bypass also provides extremely productive inundated floodplain habitat that exports nutrients and food items to the downstream river system (Sommer et al., 2001). Inundated floodplain also provides rearing habitat for steelhead and Chinook salmon, and spawning habitat for Sacramento splittail.

There is no developed land within the Sutter Bypass, and major infrastructure is limited to just several road crossings (most notably SR 113), several interconnected electrical transmission lines, and two major water supply canals, the West Borrow Canal and East Borrow Canal, which are immediately adjacent to the waterside toes of the western and eastern Sutter Bypass levees, respectively.

The Sutter Bypass levees are project levees whose physical condition is generally of higher concern.

Stakeholders identified potential restoration opportunities in the Sutter Bypass.

3.3.2 Yolo Bypass

To the north and east, the Yolo Bypass is bordered by the natural levees of the Sacramento River and its distributary channels, on the west by the alluvial fans of Putah Creek and Cache Creek, and to the south by the tidal sloughs and islands of the Delta. During flood flows, water enters the Yolo Bypass from the Sacramento River from the north, and Cache Creek, Putah Creek, and Willow Slough from the west; and drains south to the northern Delta. During about 70 percent of years, the bypass is inundated one to several times for 0 to 135 days during May through November (DFG, 2008).

Land cover in the Yolo Bypass consists of a mosaic of agricultural and natural vegetation that includes row crops, seasonal wetlands managed as habitat (primarily for waterfowl), permanent wetlands, and uplands. Riparian and wetland-associated sensitive species documented along this reach include giant garter snake, California black rail, and Swainson’s hawk. Also, as described for the Sutter Bypass, the Yolo Bypass provides extremely productive inundated floodplain habitat that benefit downstream ecosystems and provide rearing habitat for steelhead and Chinook salmon, and spawning habitat for Sacramento splittail. A substantial portion of the bypass is included in the Yolo Bypass Wildlife Area.

There is no developed land in the Yolo Bypass. Infrastructure in and adjacent to the Yolo Bypass includes levees and several major transportation features. The Sacramento Deep Water Ship Channel is east of the bypass. There are a variety of small interior levees and berms constructed for local agricultural development that prevent the inundation of particular areas from tidal fluctuations and small floods. In addition, causeways and bridge crossings of the bypass include I-80, I-5, portions of the abandoned Sacramento North Railroad, and the Southern Pacific Railroad.

The Yolo Bypass is surrounded completely on the east and partially on the west by SPFC levees. The physical condition of these levees is of higher to medium concern.

Stakeholders identified potential restoration opportunities in the Yolo Bypass.

3.4 San Joaquin River Reach Descriptions

3.4.1 Friant Dam to SR 99

Along this reach, the San Joaquin River is confined by bluffs and between the bluffs by low terraces. Consequently, the corridor along the river predominantly has greater than 10 percent chance FIP. Along the river are the pits of active and abandoned aggregate mines. A number of these pits have been captured by (i.e., become connected to) the river. (These captured pits are of conservation concern because of the potential for fish stranding and predation by warm-water fish.)

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers about 8 percent of the corridor. Invasive plant species are abundant in this riparian vegetation (e.g., red sesbania (*Sesbania punicea*), blue gum (*Eucalyptus globulus*), and giant reed (*Arundo donax*)). Riparian and wetland-associated sensitive species documented along this reach include VELB and rookeries of wading birds.

More than 15 percent of the corridor along this reach has been conserved. Conserved areas include the San Joaquin River Ecological Reserve, Camp Pashayan Ecological Preserve, and several county parks and land managed by the San Joaquin River Parkway and Conservation Trust.

Developed land uses occupy nearly 30 percent of the corridor along this reach, and are most extensive south of the river. Because of its proximity to Fresno, this reach has major infrastructure throughout, particularly near SR 99, where natural gas pipelines, electrical transmission lines, and a railroad cross the river. Electrical transmission lines also cross the river near RMs 250 and 254, and SR 41 crosses the river near RM 252. In addition, there are a number of historical and several active gravel mines along this reach. Also, Sierra Sky Park Airport is within 1 mile of the river.

In addition to increasing spring–fall river flows, potential restoration actions identified for this reach by the SJRRP include isolating/eliminating selected gravel pits, modifying side channels, controlling invasive species and fish predators, modifying road crossings, and augmenting spawning gravel.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.2 SR 99 to Gravelly Ford

From SR 99 to Gravelly Ford, the San Joaquin River is confined between bluffs. At the downstream end of this reach, the bluffs diminish in height and gradually merge with floodplain surfaces. Despite this change, along this entire reach of river, the evaluated corridor primarily has greater than 10 percent chance FIP.

Natural vegetation covers only about one-eighth of the corridor along this reach, and riparian/wetland vegetation covers several percent of the corridor. Riparian and wetland-associated sensitive species have not been documented along this reach in the CNDDB.

Very little of the corridor along this reach has been conserved (less than 1 percent of the corridor). A county park (Skaggs Bridge Park) is the only conserved area along this reach of the San Joaquin River.

Developed land uses occupy less than 1 percent of the corridor along this reach. Except for a natural gas pipeline that is along the length of this reach and crosses the river twice between RMs 238 and 240, there is no major infrastructure along this reach of the San Joaquin River.

In addition to increasing spring–fall river flows, potential restoration actions identified for this reach by the SJRRP include isolating/eliminating selected gravel pits, controlling invasive plant species, and modifying road crossings. Stakeholders also identified potential restoration opportunities along this reach of the San Joaquin River. Stakeholders did not identify potential restoration opportunities along this reach of the San Joaquin River.

3.4.3 Gravelly Ford to Chowchilla Bypass

From Gravelly Ford to Chowchilla Bypass, the San Joaquin River is sand bedded and meandering. Through lateral migration and avulsion the channel actively moves within the levees. The SJRRP is restoring year-round flow to this reach that, because of diversions, has had only seasonal flow. The FIP of the corridor along this reach varies considerably, with about 40 percent having 67 percent chance Sustained Spring or 50 percent chance FIP. Most of these areas are disconnected from the river.

Natural vegetation covers more than 10 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 5 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB and Swainson’s hawk. There are no conserved areas along this reach of the San Joaquin River.

Developed land uses occupy much less than 1 percent of the corridor along this reach. There is very little major infrastructure along this reach of the San Joaquin River. A natural gas pipeline is within 1,000 feet of the river at RMs 219 to 220.

SPFC levees are along both river banks. The physical condition of these levees is of higher concern.

Stakeholders identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.4 Chowchilla Bypass to Mendota Dam

From Chowchilla Bypass to Mendota Dam, FIP varies considerably. However, nearly half of the corridor has 67 percent chance Sustained Spring or 50 percent chance FIP. Most of these areas are disconnected from the river.

The backwater of Mendota Pool occupies the lower few miles of this reach. This backwater is an extensive area of open water bordered by riparian and emergent wetland vegetation. The Mendota Pool is formed by Mendota Dam at the confluence of the San Joaquin River and Fresno Slough. The primary source of water to the Mendota Pool is conveyed from the Delta through the Delta-Mendota Canal. Most of the Mendota Pool is less than 10 feet deep, with the deepest areas no more than 20 feet deep and averaging about 400 feet wide. Inflows to and outflows from the pool are balanced so that the pool remains at a relatively constant depth. The pool must remain above 14.5 feet at the Mendota Dam gage for users at the southern end of the pool to be able to draw water.

Along this reach of the San Joaquin River, there are almost no conserved lands. However, the Mendota Wildlife Area is along the James Bypass, at the southern end of the Mendota Pool.

Natural vegetation covers nearly 15 percent of the corridor along this reach, and riparian/wetland vegetation covers about 5 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford’s arrowhead, giant garter snake, western pond turtle, and Swainson’s hawk.

Developed land uses occupy only about 1 percent of the corridor along this reach. Although San Mateo Road crosses the river in this reach and a natural gas pipeline repeatedly crosses the river between RMs 203 and 208, Mendota Dam and the diversions associated with Mendota Dam account for most major infrastructure along this reach. Also, there is a community airport at Mendota within 2 miles of the river.

There are nonproject levees on both banks of this reach. There are no project levees along this reach.

The SJRRP includes constructing a bypass channel around Mendota Pool, and setting back levees to create a floodplain between 500 and 3,700 feet wide. It also identifies modifying the San Mateo Road crossing as a potential restoration action. Stakeholders also identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.5 Mendota Dam to Sack Dam

Along this reach, regulated flows for water deliveries from the Delta-Mendota Canal are conveyed through the San Joaquin River channel to Sack Dam for diversion to Arroyo Canal.

From Mendota Dam to Sack Dam, about two-thirds of the corridor along the river has 50 percent chance FIP, and most of the remainder (mostly located near Firebaugh) has greater than 10 percent chance FIP. Along this reach, nearly 90 percent of areas with 50 percent chance FIP are disconnected from the river.

Natural vegetation covers about an eighth of the corridor along this reach, and riparian/wetland vegetation covers less than 4 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include giant garter snake, western pond turtle, Swainson’s hawk, and western red bat. There is almost no conserved area along this reach of the San Joaquin River.

Developed land uses occupy about 5 percent of the corridor along this reach, and are extensive in the vicinity of Firebaugh on the west bank. Major infrastructure along this reach includes a crossing by Avenue 7 ½; electrical transmission line crossings near RMs 184, 185, and 195; a natural gas pipeline crossing near RM 192; and a gravel mine near RM 188. There is also a community airport at Firebaugh that is within 1 mile of the river.

For most of its length, this reach is bounded on both sides by man-made structures, including irrigation canals and project and nonproject levees. There are no project levees along this reach. At some locations, lands within the floodway are actively used for agricultural production, and are protected by local or interior levees. During the 2006 flood, a number of these parcels were inundated.

The SJRRP has not planned or identified any restoration actions along this reach other than modification of facilities to improve fish passage, and the previously described Mendota Pool Bypass, which would reconnect to the river at the beginning of this reach. Stakeholders, however, identified a potential restoration opportunity along this reach of the San Joaquin River.

3.4.6 Sack Dam to Sand Slough Control Structure

From Sack Dam to the Sand Slough Control Structure, the geomorphology of the San Joaquin River is transitional from the meandering river channel and associated floodplain of upstream reaches to the numerous sloughs and extensive floodbasins downstream. Many sloughs originate in this and the immediately downstream reach of the San Joaquin River.

This reach normally carries only seepage water from Sack Dam and from adjacent agricultural areas. At its downstream end, any water in the channel flows through Sand Slough and into the Eastside Bypass.

Along this reach, the floodway is only about 300 feet wide. Outside of this floodway, the corridor along the river consists predominantly of areas with 50 percent chance FIP, which are disconnected from the river.

Natural vegetation covers about an eighth of the corridor along this reach, but riparian/wetland vegetation covers less than 2 percent of the corridor. Swainson’s hawk has been documented along this reach. There are no conserved lands along this reach of the San Joaquin River.

The floodplain of this reach is almost entirely in agricultural use. It virtually lacks developed land uses and has relatively little major infrastructure: SR 152 crosses the river at RM 173, an electrical transmission line crosses the river at RM 173, and a natural gas pipeline crosses the river near Sack Dam.

Nonproject levees are close to the river along all of this reach except at the northern end, where there are SPFC levees. The physical condition of these project levees is of higher concern.

The SJRRP includes projects to modify Sack Dam (to improve fish passage) and to screen the intake of the Arroyo Canal. Stakeholders did not identify potential restoration opportunities along this reach of the San Joaquin River.

3.4.7 Sand Slough Control Structure to Mariposa Bypass

In this reach, the channel of the San Joaquin River historically was connected to sloughs and floodbasins. Consequently, more than two-thirds of the corridor along the river has 67 percent chance FIP, and most of the remainder has Below Baseflow FIP. This reach has the largest percentage of 67 percent chance FIP among reaches of the San Joaquin and

Sacramento river systems. About 60 percent of these areas are disconnected from the river.

Natural vegetation covers nearly 15 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 3 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery (*Eryngium racemosum*), giant garter snake, northern harrier (*Circus cyaneus*), and Swainson's hawk.

More than 5 percent of the corridor along this reach has been conserved. This conserved land is part of the San Luis National Wildlife Refuge.

This reach virtually lacks developed land uses. Other than the Sand Slough Control Structure and the Mariposa Bypass at the ends of this reach, and several levees, this reach also has almost no major infrastructure. SPFC levees are on both banks at the northern end of this reach, and nonproject levees are at two locations farther upstream. The physical condition of the SPFC levees is of higher concern.

The SJRRP includes increasing conveyance in this reach, potentially with setback levees, modifying road crossings, and modifying the San Slough Control Structure to improve fish passage and the San Joaquin River Headgate to allow improve conveyance.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.8 Mariposa Bypass to Bear Creek

From the Mariposa Bypass to Bear Creek, the San Joaquin River was historically connected to sloughs and floodbasins. Approximately 90 percent of the corridor along this reach has 50 percent chance FIP. Most of this area is disconnected from the river.

Natural vegetation covers more than 90 percent of the corridor along this reach, and riparian/wetland vegetation covers nearly 15 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, northern harrier, and Swainson's hawk.

More than 70 percent of the corridor along this reach of the San Joaquin River has been conserved. Unlike most reaches, the majority of this conserved land is disconnected from the river. Conserved areas along this reach include a portion of the San Luis National Wildlife Refuge.

This reach virtually lacks developed land uses. There is very little major infrastructure along this reach other than an electrical transmission line that crosses the river at RM 142.

SPFC levees are on both banks along this reach. The physical condition of these levees is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.9 Bear Creek to Merced River

From Bear Creek to the Merced River, the San Joaquin River has more sinuosity than in upstream reaches; and oxbow, side channel, and remnant channel landforms are present. About half of the corridor along the river has a 50 percent chance FIP, and most of these areas are connected to the river.

Natural vegetation covers more than 70 percent of the corridor along this reach, and riparian/wetland vegetation covers nearly 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, western pond turtle, colonies of tricolored blackbirds, northern harrier, Swainson's hawk, western red bat, and pallid bat (*Antrozous pallidus*).

More than 50 percent of this reach of the San Joaquin River has been preserved. Conserved areas along this reach include the North Grasslands Wildlife Area, Great Valley Grasslands State Park, and San Luis National Wildlife Refuge.

Developed land uses occupy only about 2 percent of the corridor along this reach. There is little major infrastructure along this reach: an electrical transmission line is located near the river at RM 116, SR 140 crosses the river near RM 123, and Lander Avenue crosses the river near RM 130.

An SPFC levee is located along the river's east side, and extends for several miles along the west side. The physical condition of the east levee is of medium concern; the physical condition of the west levee is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.10 Merced River to Tuolumne River

Between the Merced and Tuolumne rivers, the San Joaquin River is sinuous and in some areas is actively meandering. The corridor along this reach of the San Joaquin River includes abandoned sloughs, channel portions, and oxbow cutoffs. In this reach, more than half of the corridor along the San Joaquin River has a 10 percent chance or greater than a 10 percent chance FIP. A 50 percent chance FIP accounts for almost 40 percent of the corridor, and about half of these areas are disconnected from the river.

Natural vegetation covers more than 30 percent of the corridor along this reach, and riparian/wetland vegetation covers about 6 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Delta button-celery, VELB, wading bird rookeries, least Bell's vireo (*Vireo bellii pusillus*), colonies of tricolored blackbirds, Swainson's hawk, pallid bat, and western red bat. This reach also provides habitat for Sacramento splittail; and migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a small portion of the corridor along this reach of the San Joaquin River has been conserved (approximately 5 percent of the corridor). However, there are several conserved areas along this reach, including the West Hilmar Wildlife Area, a portion of the San Joaquin National Wildlife Refuge, and several county and regional parks and open space areas.

Developed land uses occupy about 5 percent of the corridor along this reach. However, major infrastructure is widely dispersed along this reach. Electrical transmission lines cross the river near RMs 85, 87, and 101, and pipelines cross the river near RMs 101 and 107. In addition to these crossings, a wastewater treatment facility is on the east bank at RMs 94 and 93, and an aggregate mine is near RM 107.

SPFC levees are along most of the east bank and portions of the west bank, but neither connects to other SPFC levees upstream or downstream from this reach. The physical condition of these levees is of higher concern, except for a west levee at the junction with the Tuolumne River, whose physical condition is of medium concern. There are several nonproject levees in intervening areas.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.11 Tuolumne River to Stanislaus River

The San Joaquin River is actively meandering in portions of this reach, and the river corridor includes floodplain with complex topography, including oxbows, swales, and other products of channel migration. Between the

Tuolumne and Stanislaus rivers, nearly half of the corridor along the San Joaquin River has a 50 percent chance FIP, and most of the remainder has either 10 percent chance or greater than a 10 percent chance FIP. Approximately 60 percent of areas with a 50 percent chance FIP are disconnected from the river.

Natural vegetation covers nearly half of the corridor along this reach, and riparian/wetland vegetation covers more than 10 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, least Bell's vireo, colonies of tricolored blackbirds, Swainson's hawk, riparian woodrat (*Neotoma fuscipes riparia*), and riparian brush rabbit (*Sylvilagus bachmani riparius*). This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

More than one-third of the corridor along this reach of the San Joaquin River has been conserved. This conserved land is part of the San Joaquin National Wildlife Refuge.

This reach virtually lacks developed land uses. Along this reach, there is little major infrastructure except for levees: between RM 78 and RM 75, Maze Boulevard, and an electrical transmission line cross the river.

There are SPFC levees on portions of both banks and nonproject levees connecting to and/or inside of the SPFC levees. The physical condition of these levees is of higher concern.

Stakeholders identified potential restoration opportunities along this reach of the San Joaquin River.

3.4.12 Stanislaus River to Stockton

The San Joaquin River is actively migrating in portions of this reach, and the corridor along the river includes floodplains with complex topography and oxbow lakes. From the Stanislaus River to Stockton, about 40 percent of the corridor along the San Joaquin River has a 50 percent chance FIP, and most of the remainder is distributed relatively evenly between areas with Below Base Flow, a 67 percent chance Sustained Spring, and a 10 percent chance FIP. About 90 percent of areas with a 67 percent chance Sustained Spring or 50 percent chance FIP are disconnected from the river. In this tidally influenced reach, the San Joaquin River enters the legal Delta.

Natural vegetation covers approximately 10 percent of the corridor along this reach, and riparian/wetland vegetation covers approximately 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include Sanford's arrowhead, Delta button-celery, several plants associated with marshes and sloughs (e.g., slough thistle (*Cirsium crassicaule*)), Suisun song sparrow (*Melospiza melodia maxillaris*), colonies of tricolored blackbirds, Swainson's hawk, riparian woodrat, and riparian brush rabbit. This reach also provides habitat for several sensitive fish species, including foraging adult green sturgeon; and migrating, holding, and rearing steelhead and fall-run Chinook salmon; and this reach contains delta smelt designated critical habitat.

Only a very small portion of the corridor along this reach has been conserved (approximately 1 percent of the corridor). The only conserved area along this reach is a small preserve near Vernalis.

Developed land uses are extensive, occupying more than one-quarter of the corridor along this reach. This reach of the San Joaquin River has a high density of major infrastructure that not only includes major road and railroad, natural gas pipeline, and electrical transmission line crossings, but also aggregate mines and refineries. However, there is no major infrastructure between RMs 43 and 46, RMs 47 and 56, and RMs 61 and 65.

Except for an upstream portion of the west bank, there are SPFC levees on both banks along this reach. The physical condition of these levees is predominantly of higher concern, but there are sections on both banks (that total several miles in length) whose physical condition is of medium or lower concern.

Stakeholders identified a potential restoration opportunity along this reach of the San Joaquin River.

3.5 San Joaquin River Tributary Reach Descriptions

The lowermost reach of the Merced, Tuolumne, and Stanislaus rivers were evaluated. These reaches begin approximately 1 mile upstream from the tributary's junction with the Sacramento River because the corridor along the Sacramento River extends 1 mile from the centerline of the Sacramento River.

3.5.1 Merced River

The lowermost reach of the Merced River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, almost three-quarters of the corridor along this reach has a greater than 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, most of which is connected to the river.

Natural vegetation covers nearly 10 percent of the corridor along this reach, and riparian/wetland vegetation covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, Swainson's hawk, pallid bat, and western red bat. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a very small portion of the corridor along this reach of the Merced River has been conserved (less than 1 percent of the corridor). Conserved areas along this reach are limited to the George J. Hatfield State Recreation Area and a county park.

Developed land uses occupy about 8 percent of the corridor along this reach. Although dispersed throughout the reach, they are more extensive near Livingston at the upstream end of the reach. Major infrastructure along this reach includes a gravel mine near RM 17, and road crossings by Landers Avenue at RM 12 and SR 99 near RM 21. Additionally, a natural gas pipeline, an oil pipeline, and an electrical transmission line cross the river within this reach.

There also are nonproject levees on the south bank of this reach at several locations, but no project levees.

Stakeholders identified potential restoration opportunities along this reach of the Merced River.

3.5.2 Tuolumne River

Similar to the Merced River, the lowermost reach of the Tuolumne River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, nearly 90 percent of the corridor along this reach has a greater than 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, about half of which is connected to the river.

Natural vegetation covers nearly an eighth of the corridor along this reach, and riparian/wetland vegetation covers about 2 percent of the corridor. Riparian and wetland-associated sensitive species documented along this reach include VELB, colonies of tricolored blackbirds, and Swainson's hawk. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Only a small portion of this reach of the Tuolumne River has been conserved (nearly 5 percent of the corridor). Conserved areas along this reach include the Tuolumne River and Ceres River Bluff regional parks.

Developed land uses occupy more than one-third of the corridor along this reach. Although located throughout the reach, developed land uses and major infrastructure are most extensive at Modesto (from RMs 10 to 22).

Major infrastructure is concentrated between approximately RM 13 and RM 22. In that stretch there are major road and railroad, electrical transmission line, and natural gas pipeline crossings. The Modesto City-County Airport is also located within 1 mile of the river in this area.

There are several nonproject levees on portions of each bank along this reach, but no project levees.

Stakeholders identified potential restoration opportunities along this reach of the Tuolumne River.

3.5.3 Stanislaus River

Similar to the Merced and Tuolumne rivers, the lowermost reach of the Stanislaus River has a relatively narrow floodplain constrained by uplands of higher elevation. Consequently, more than half of the corridor along this reach has a greater than 10 percent chance FIP, and most of the remainder has a 10 percent chance FIP. Only a very small area of floodplain has a 50 percent chance FIP or a 67 percent chance Sustained Spring FIP, more than two-thirds of which is disconnected from the river.

Natural vegetation covers more than 15 percent of the corridor along this reach, but riparian/wetland vegetation accounts for about half of that land cover. Riparian and wetland-associated sensitive species documented along this reach include VELB, Swainson’s hawk, riparian woodrat, and riparian brush rabbit. This reach also provides habitat for migrating, holding, and rearing, steelhead and fall-run Chinook salmon.

Nearly 15 percent of the corridor along this reach of the Stanislaus River has been conserved. Conserved areas along this reach of the Stanislaus River include Caswell State Park and San Joaquin National Wildlife Refuge.

Developed land uses occupy about 9 percent of the corridor along this reach. Although some developed land uses are located throughout the reach, they are extensive at Ripon (RMs 12 to 14). Along this reach, there is little major infrastructure besides project and nonproject levees. Natural gas pipelines cross the river near RM 4 and RM 15.

SPFC levees are on both banks for about the first 10 river miles. The physical condition of these project levees is of higher concern. Nonproject levees extend upstream discontinuously along both sides of the river.

Stakeholders identified potential restoration opportunities along this reach of the Stanislaus River.

3.6 Maps and Tables of Results

This section provides a set of maps (Figures 3-2 through 3-26) and tables (Tables 3-1 through 3-12) for 2-mile-wide corridors along (1) Sacramento River reaches, (2) Sacramento River tributary and bypass reaches, (3) upper San Joaquin River reaches, and (4) lower San Joaquin River reaches. Each set includes maps of FIP, land use/land cover, conserved areas, and major infrastructure. Each set also includes a map of nonurban floodplain areas with a 67 percent chance Sustained Spring or a 50 percent chance FIP classified by their connectivity to the river system and their land use/land cover. (Areas with a 67 percent chance Sustained Spring or a 50 percent chance FIP represent those areas with the greatest potential for providing inundated floodplain habitats.) This map represents different types of restoration opportunities. Each set of tables summarizes information displayed on the maps by reach, including FIP and connectivity, and land cover and conservation status for selected areas.

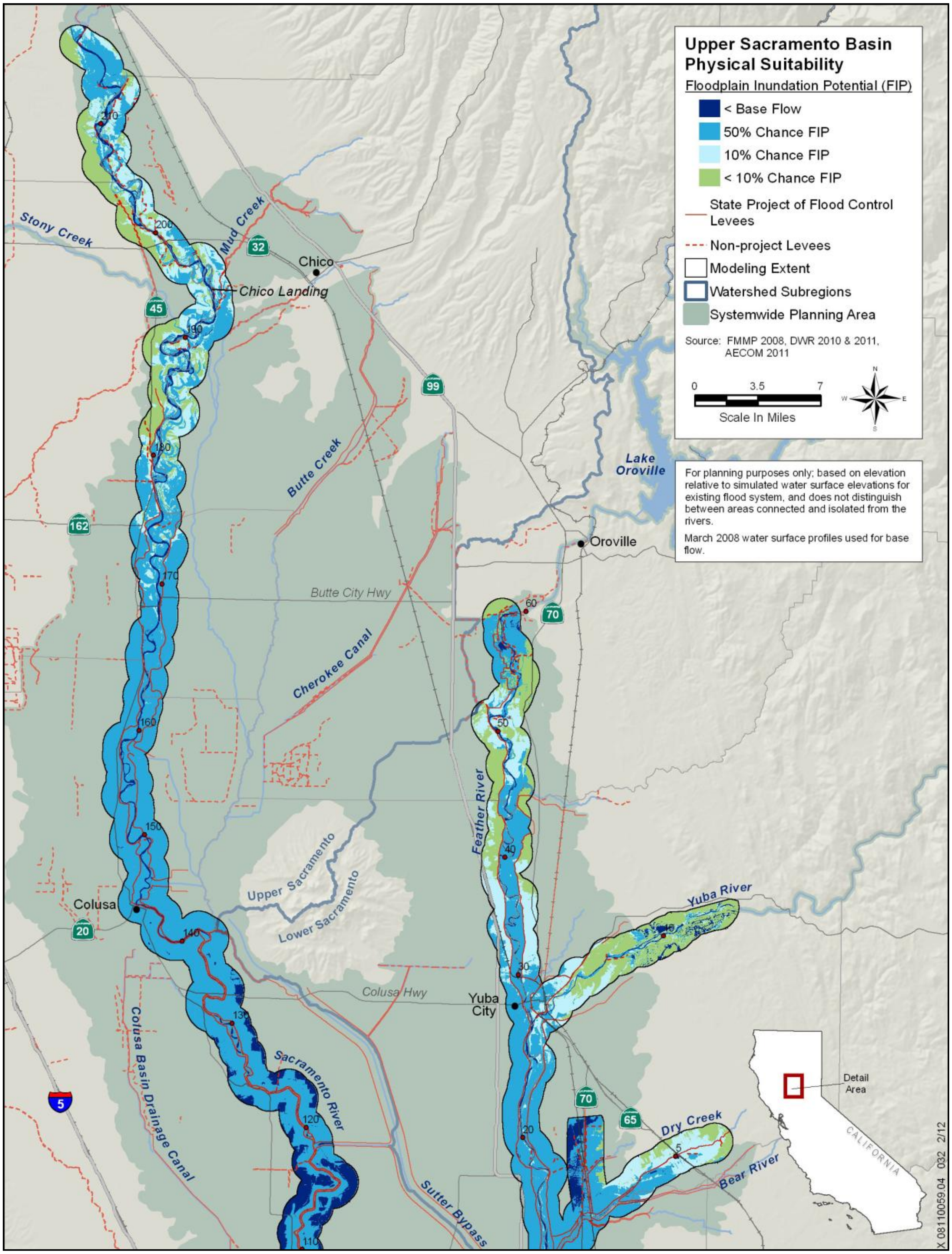

Figure 3-2. Floodplain Inundation Potential of Major River Corridors in the Upper Sacramento Basin

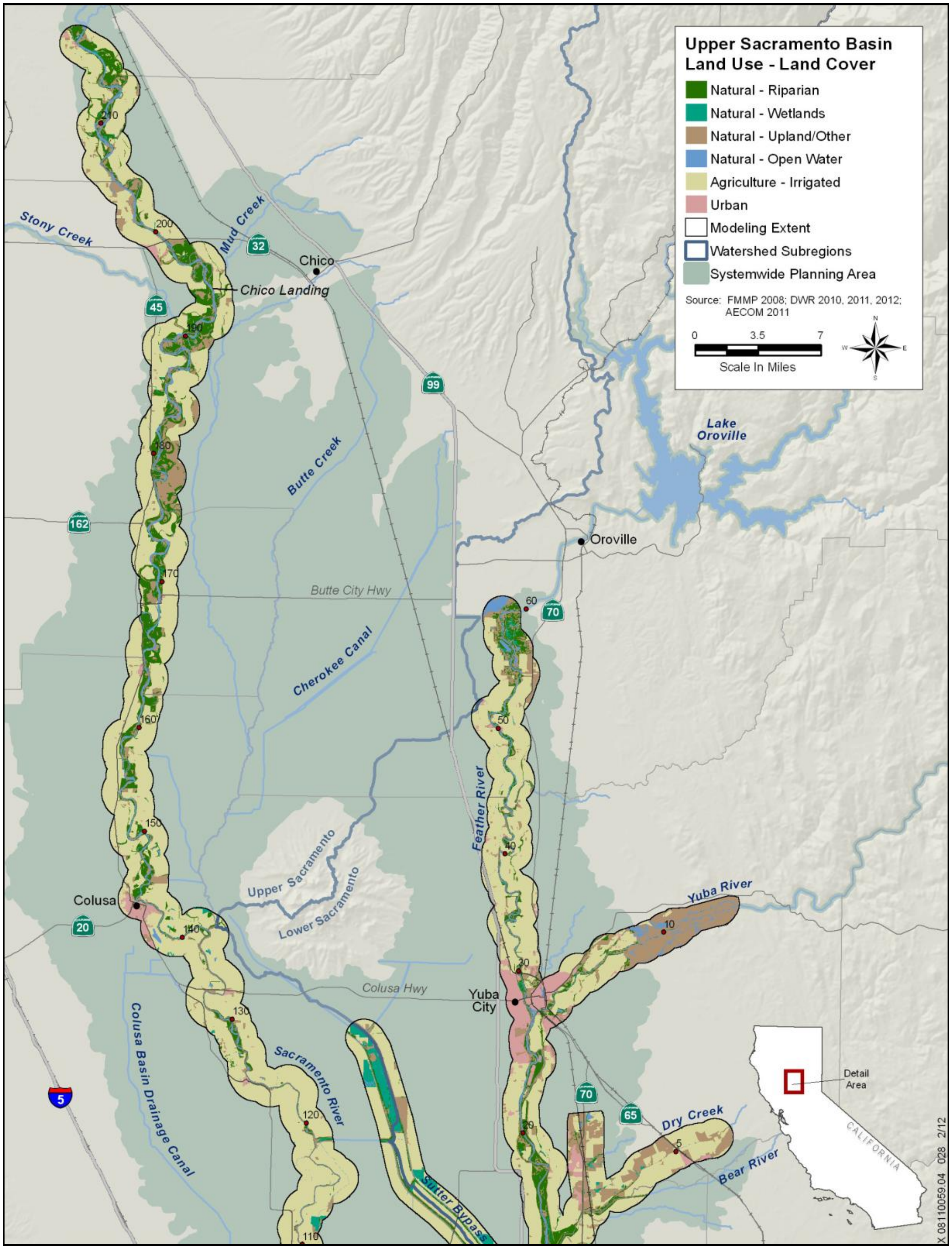

Figure 3-3. Land Use/Land Cover of River Corridors in the Upper Sacramento Basin

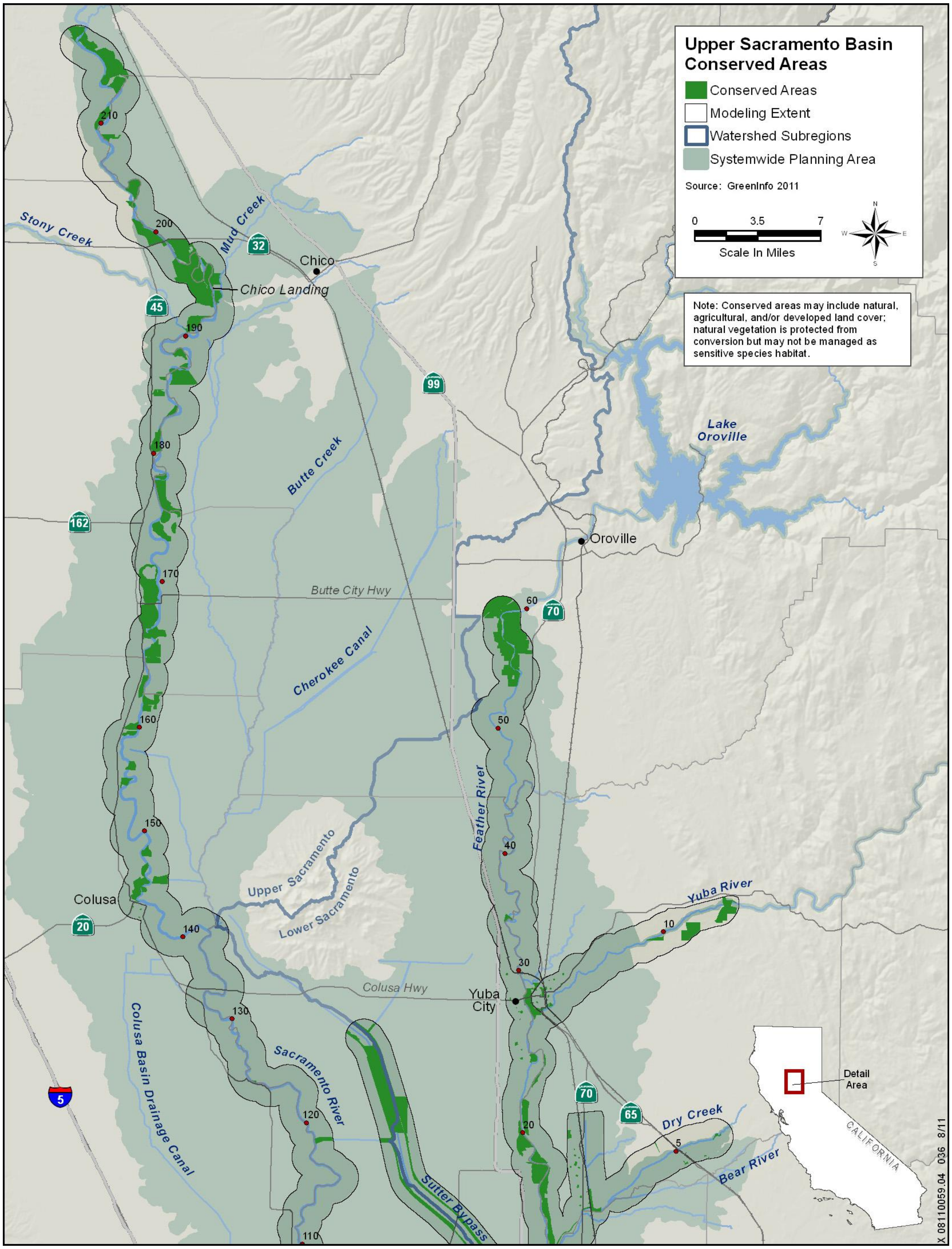

Figure 3-4. Conserved Areas of River Corridors in the Upper Sacramento Basin

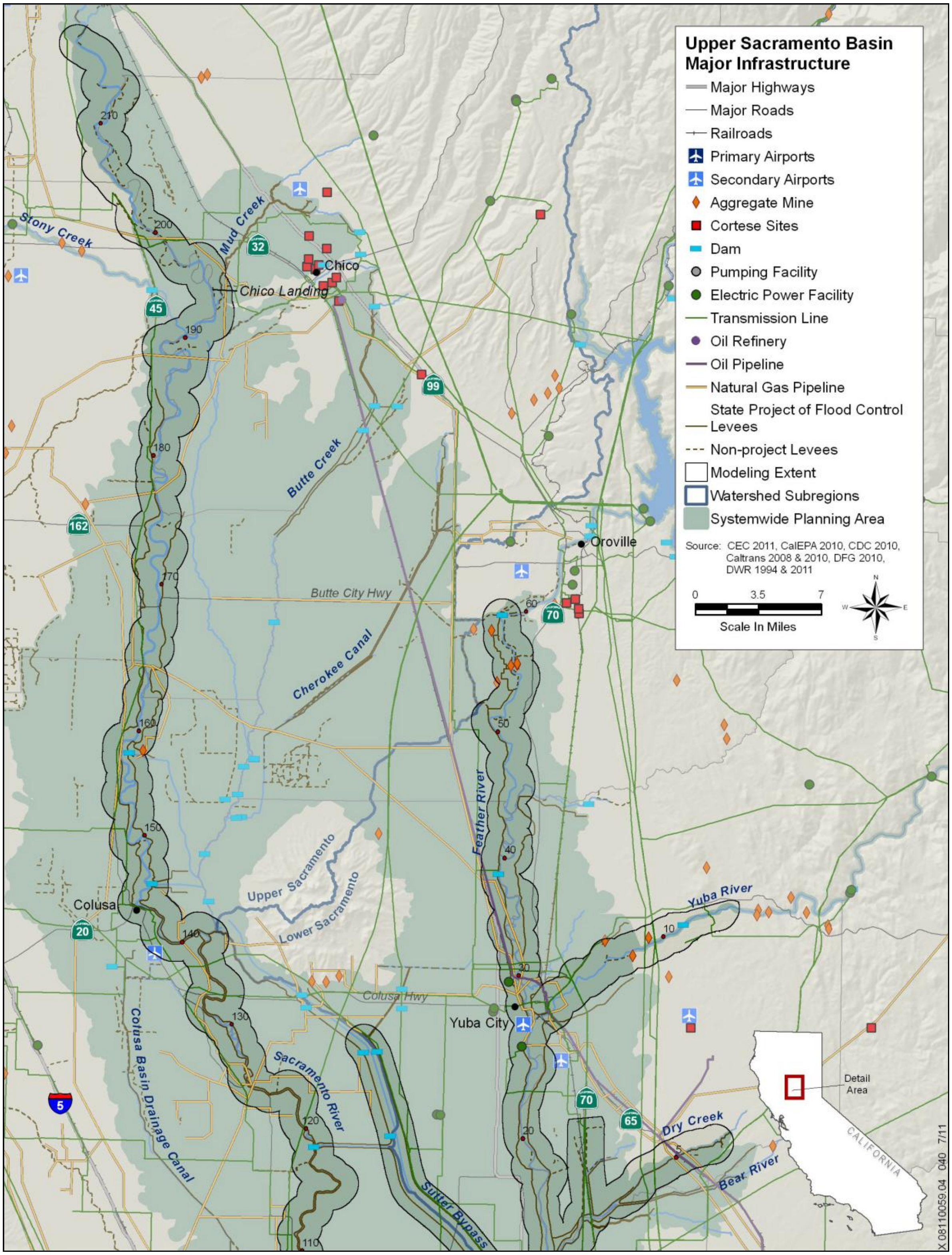

Figure 3-5. Major Infrastructure in River Corridors in the Upper Sacramento Basin

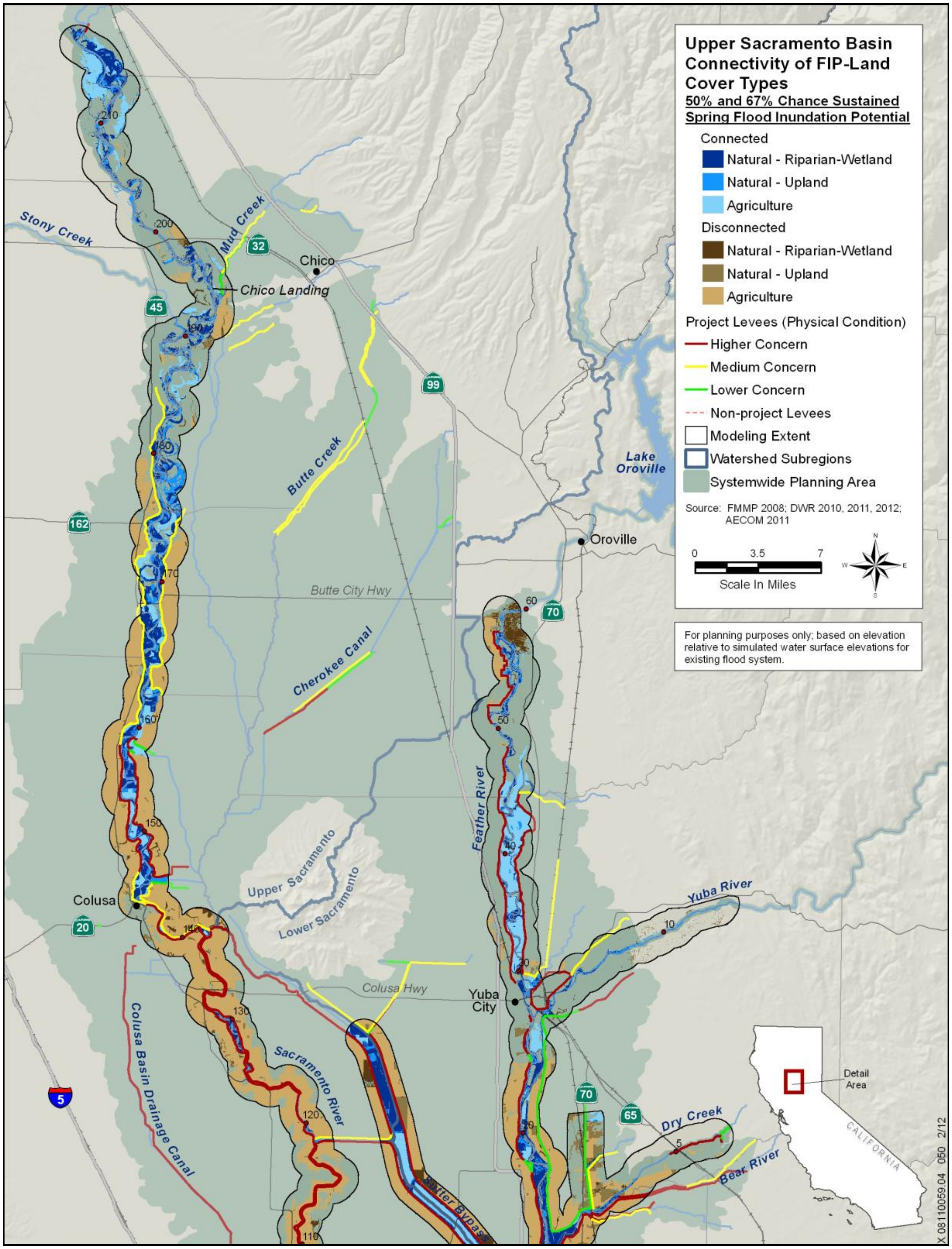

Figure 3-6. Connectivity of FIP-Land Cover Types in the Upper Sacramento Basin

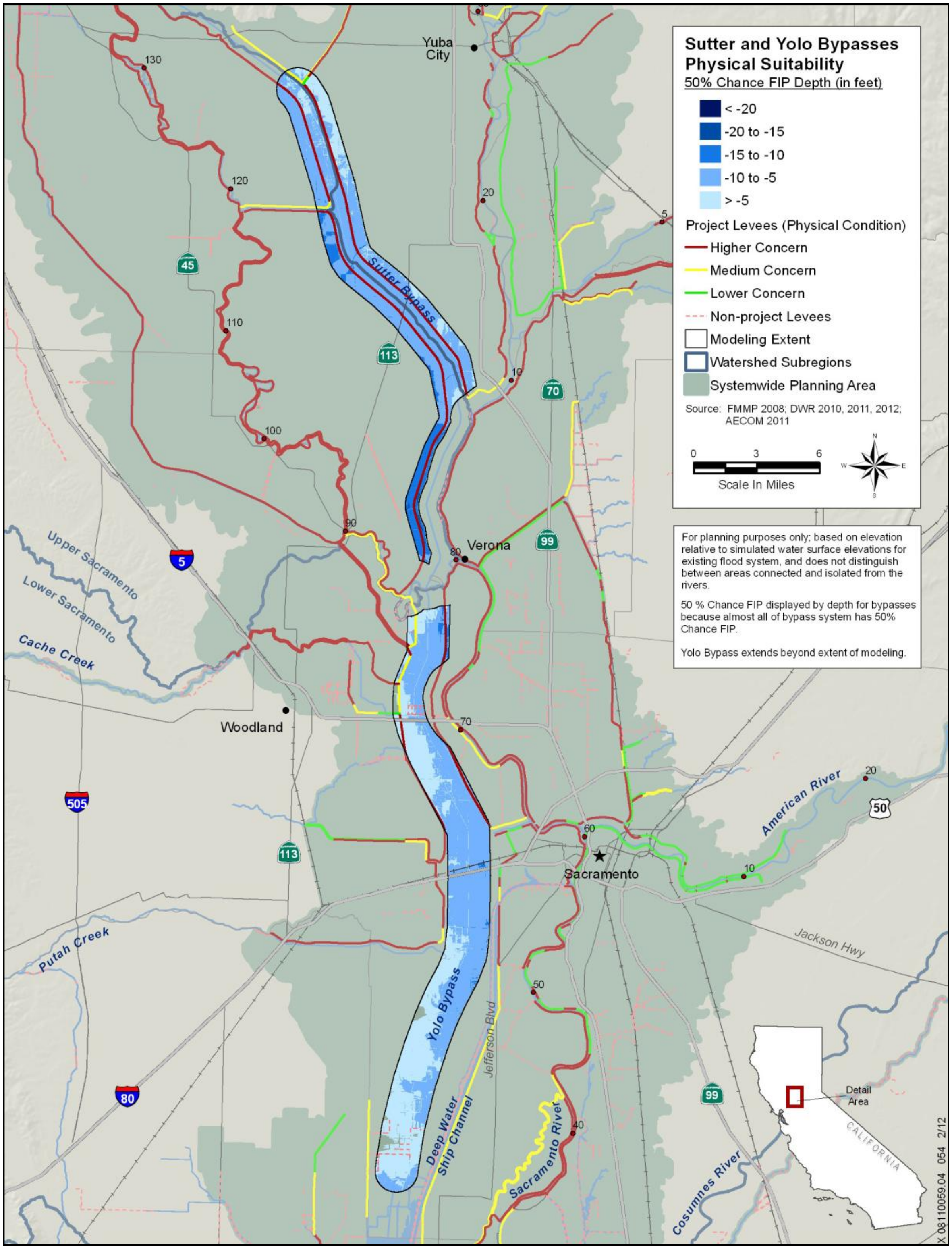

Figure 3-7. Depth of 50 Percent Chance Floodplain Inundation Potential in the Sutter and Yolo Bypasses

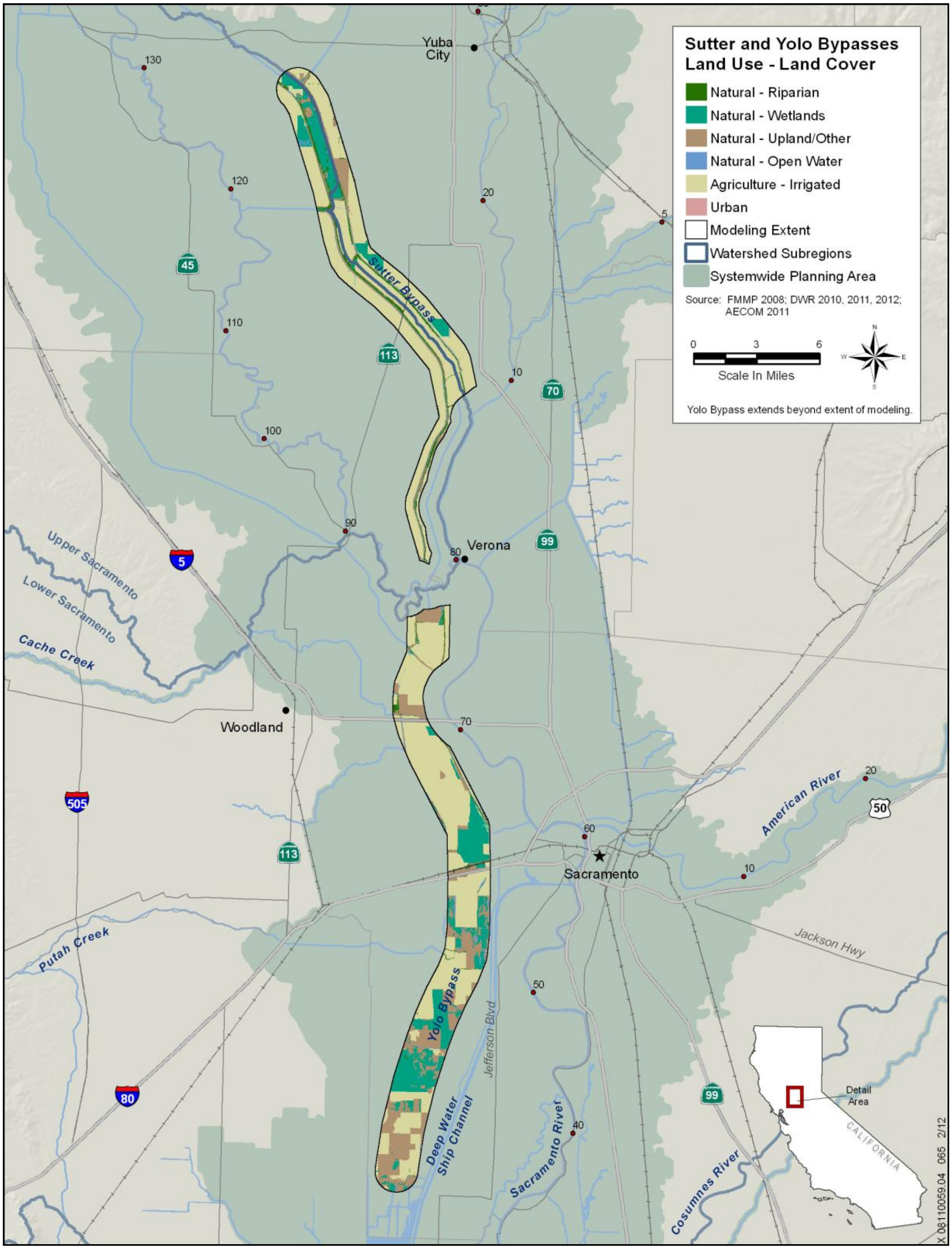

Figure 3-8. Land Use/Land Cover of River Corridors in the Sutter and Yolo Bypasses

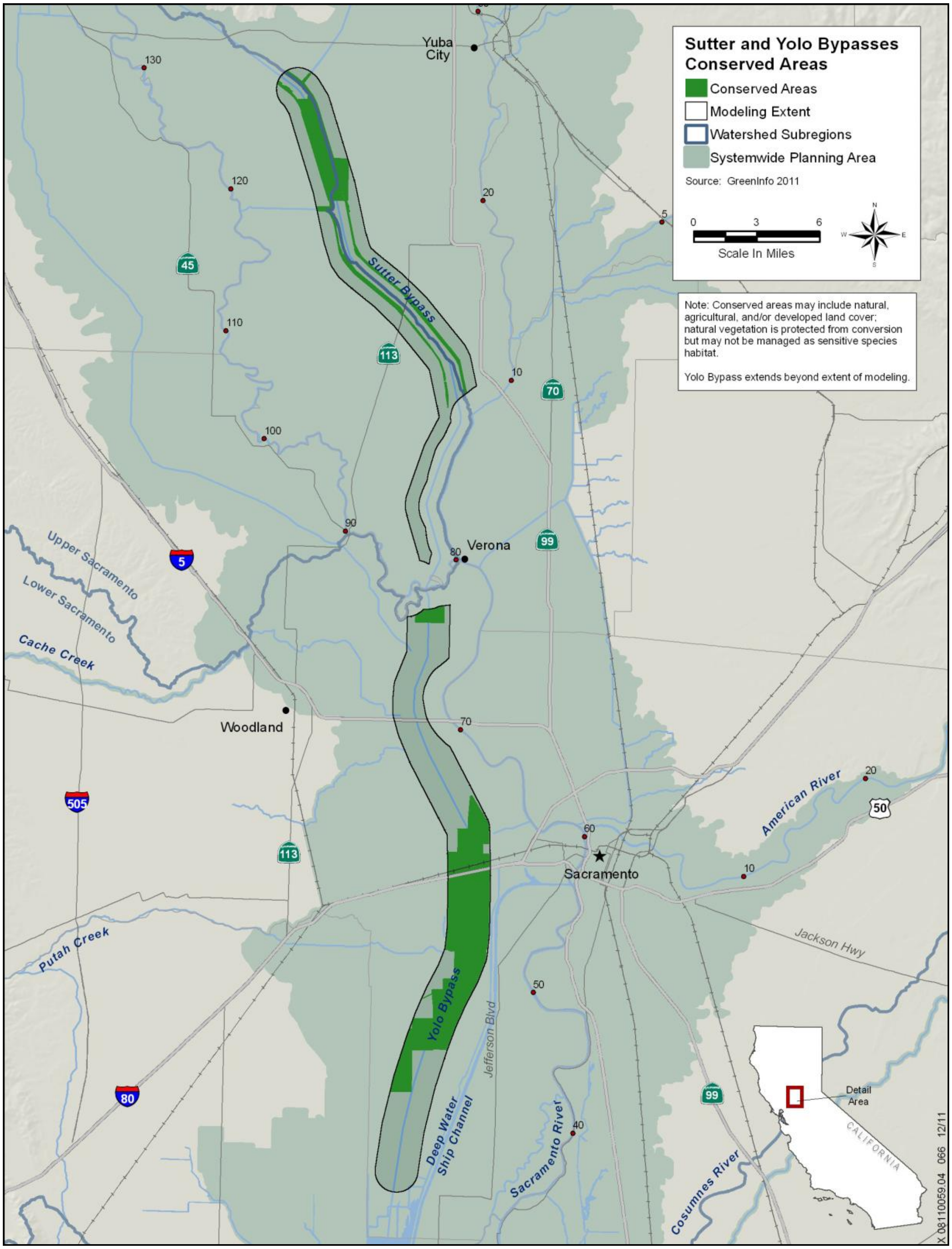

Figure 3-9. Conserved Areas of River Corridors in the Sutter and Yolo Bypasses

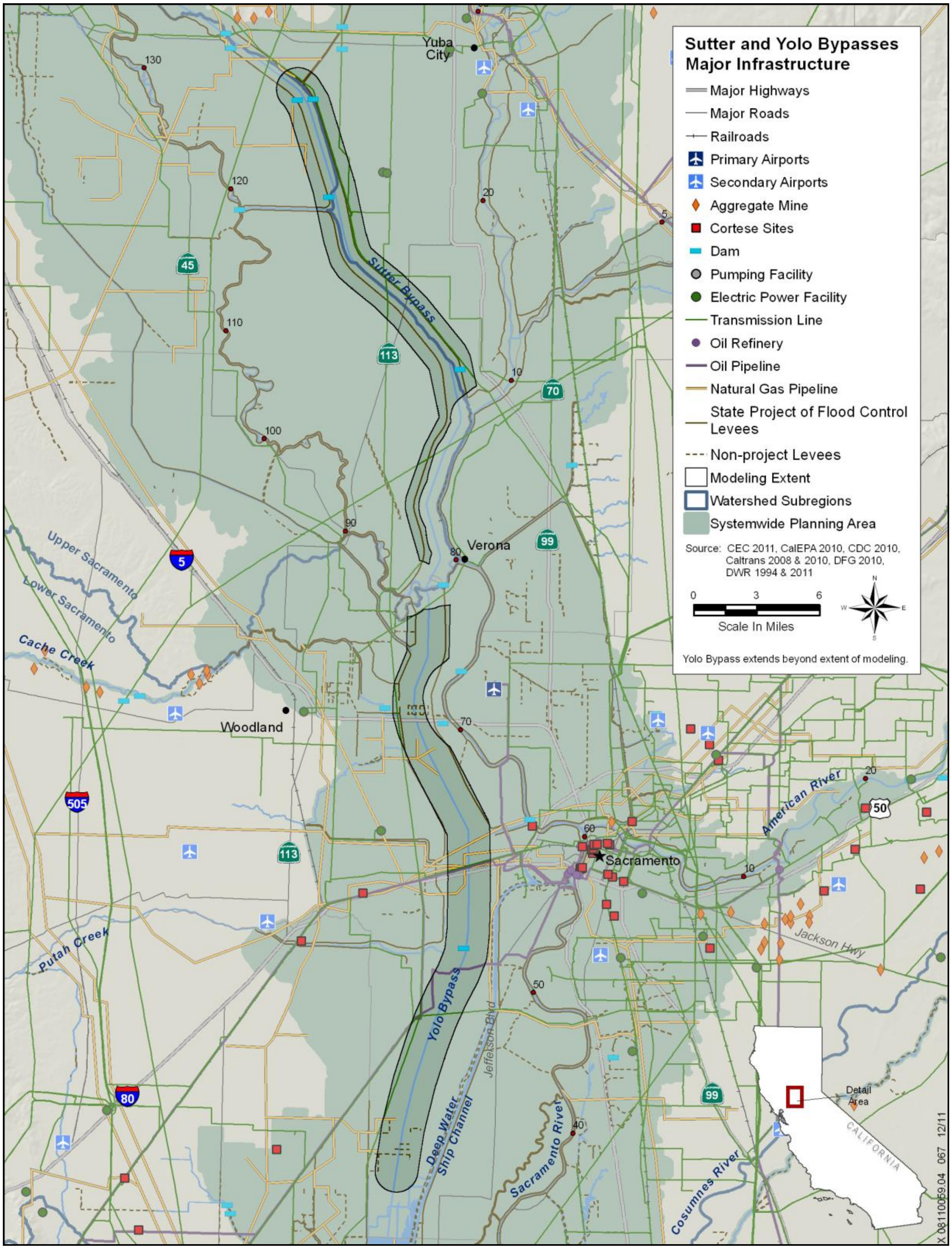

Figure 3-10. Major Infrastructure in River Corridors in the Sutter and Yolo Bypasses

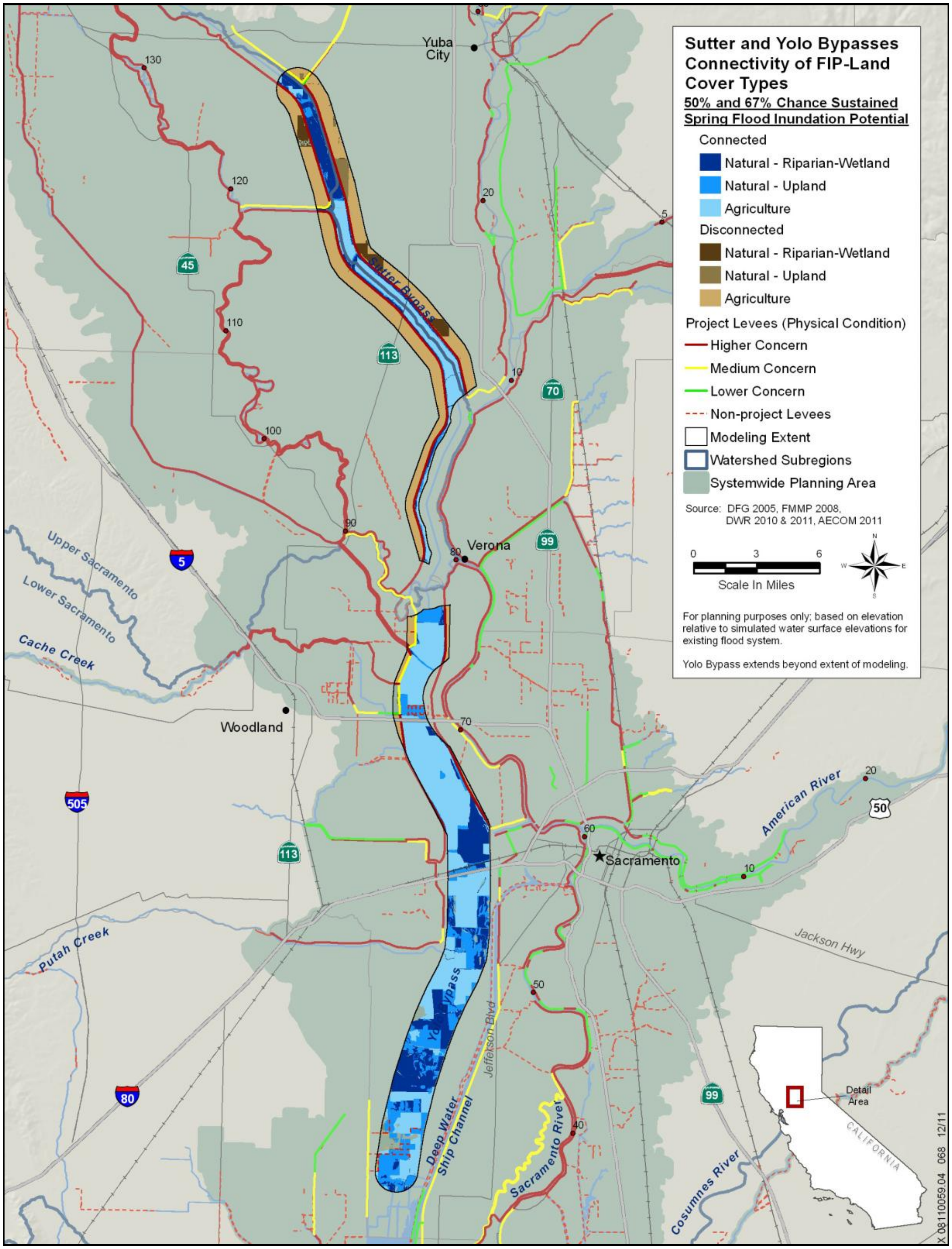

Figure 3-11. Connectivity of FIP-Land Cover Types in the Sutter and Yolo Bypasses

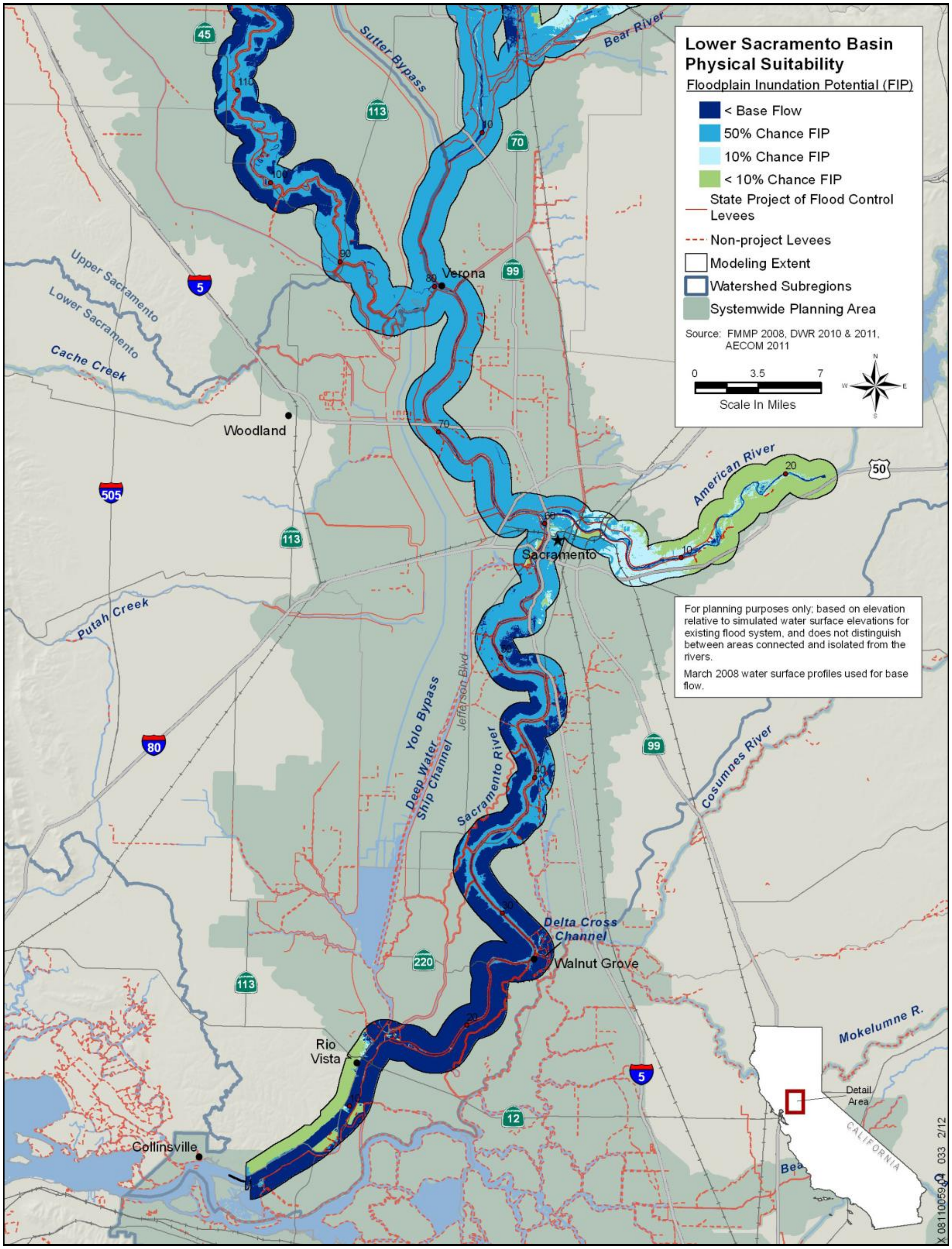

Figure 3-12. Floodplain Inundation Potential of Major River Corridors in the Lower Sacramento Basin

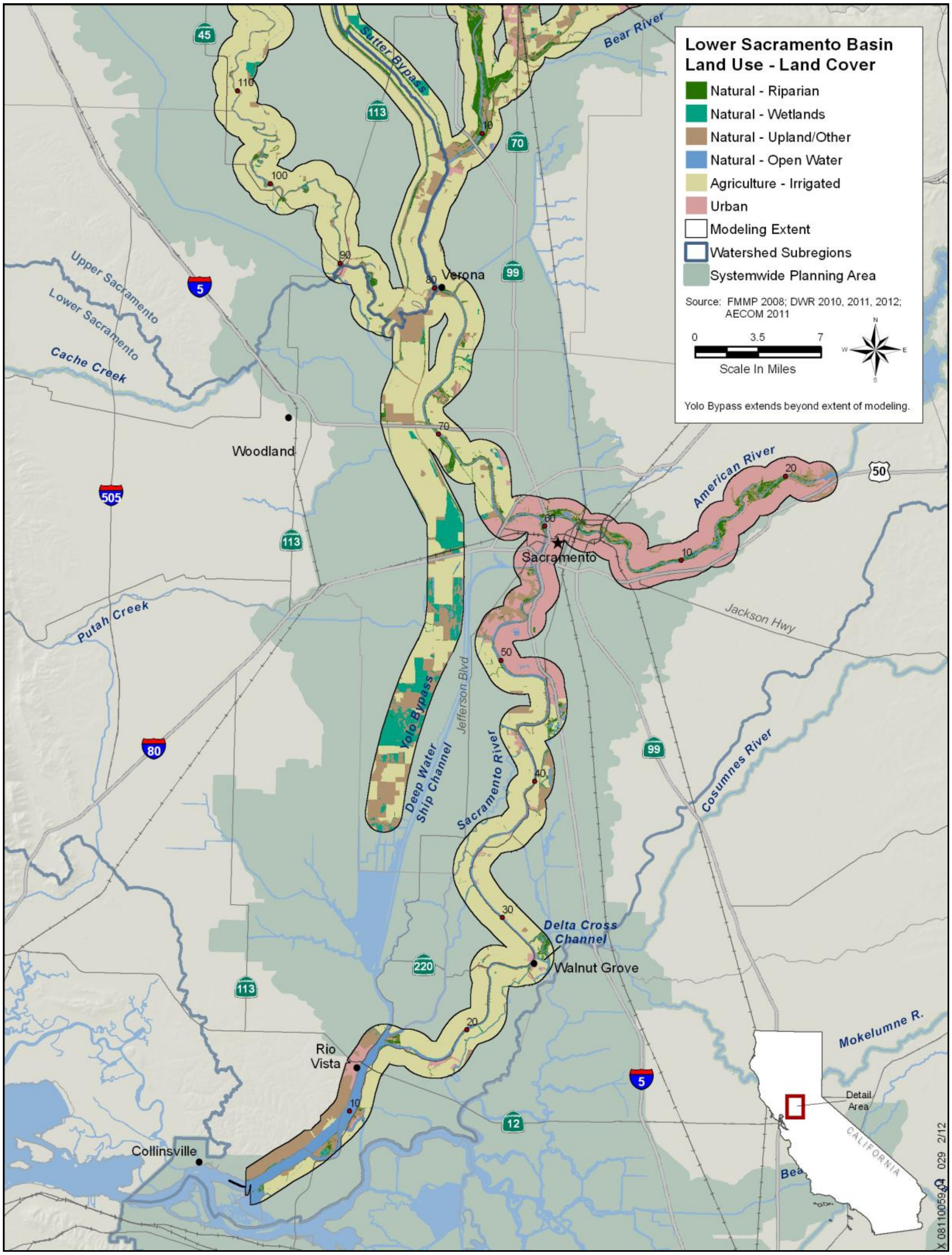

Figure 3-13. Land Use/Land Cover of River Corridors in the Lower Sacramento Basin

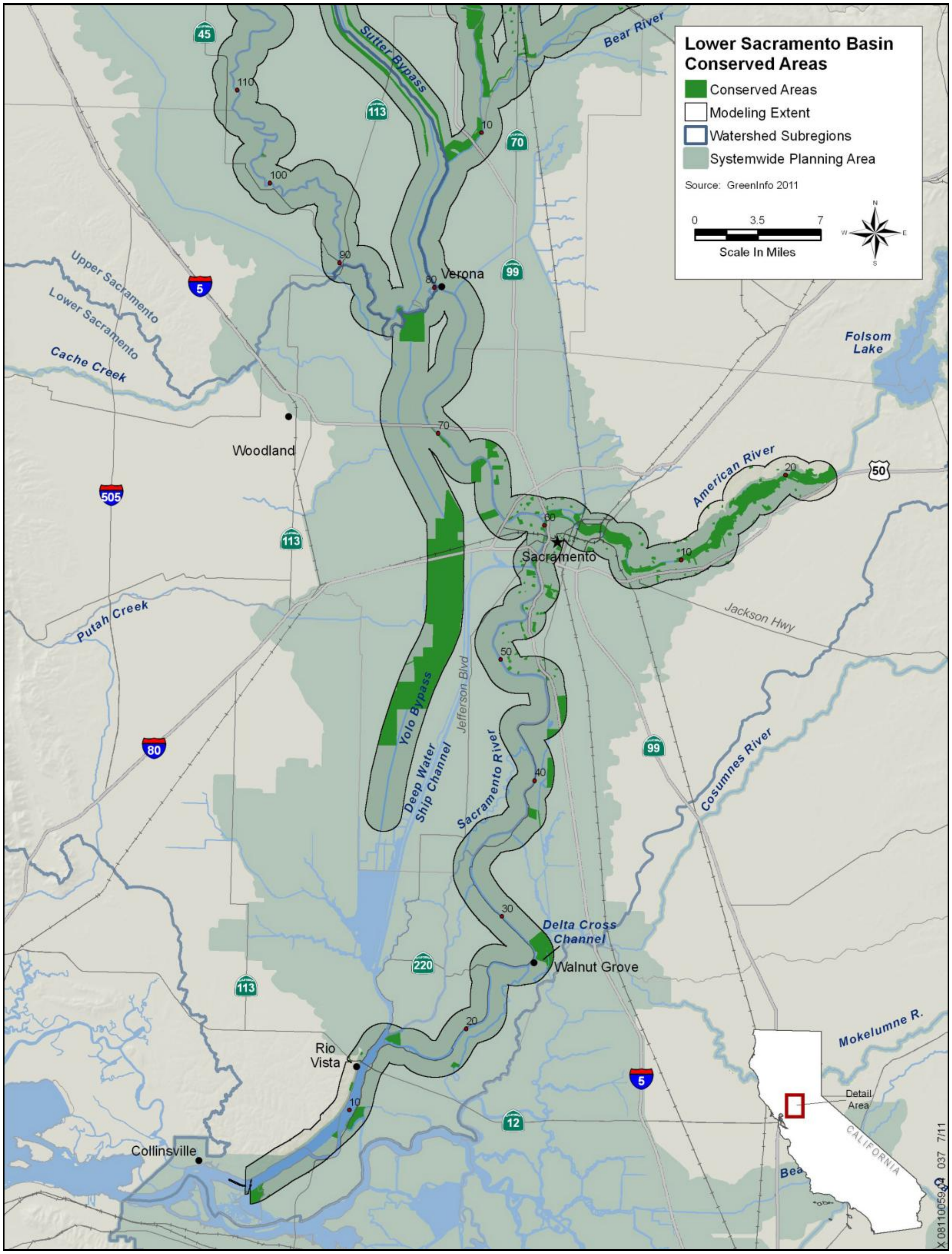

Figure 3-14. Conserved Areas of River Corridors in the Lower Sacramento Basin

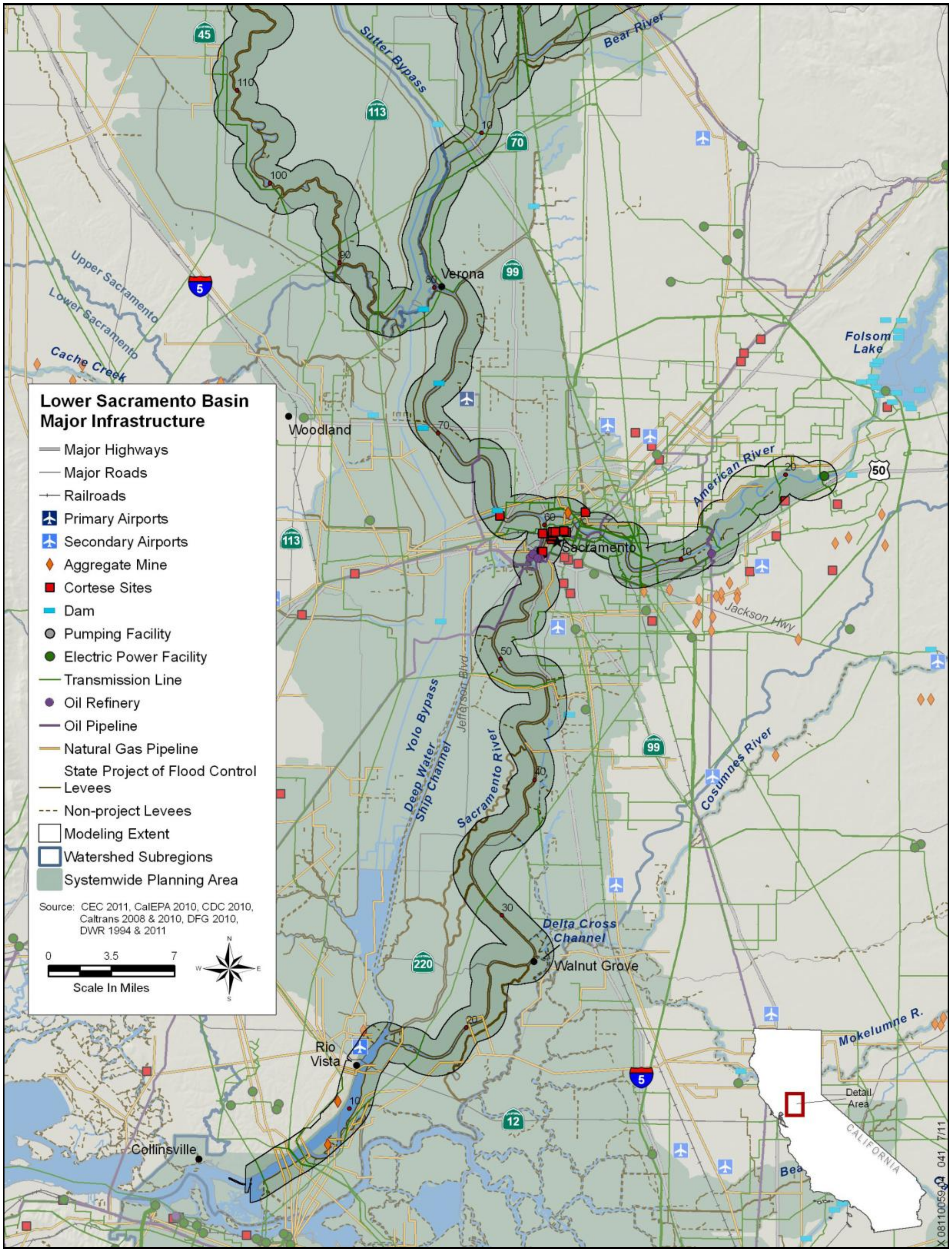

Figure 3-15. Major Infrastructure in River Corridors in the Lower Sacramento Basin

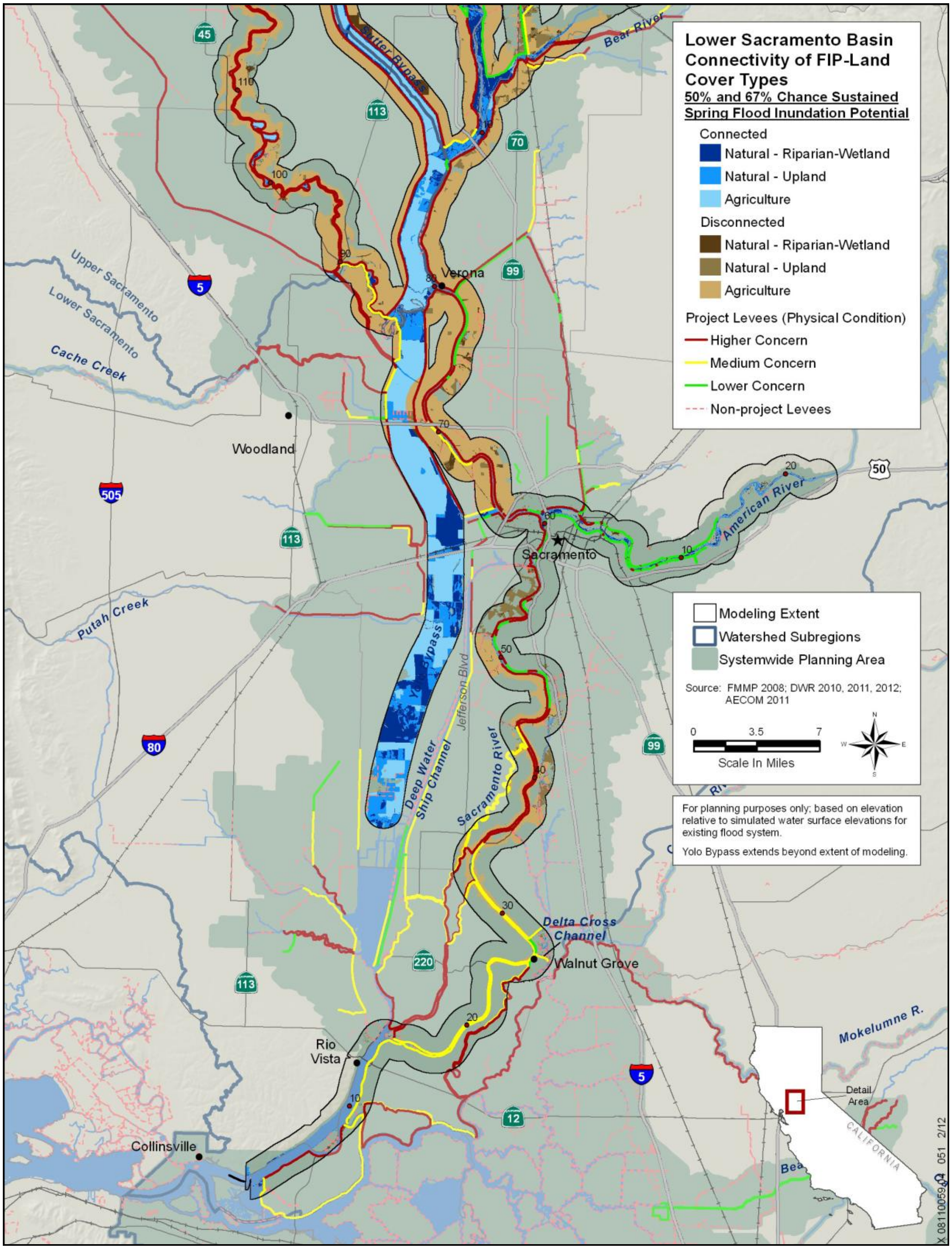

Figure 3-16. Connectivity of FIP-Land Cover Types in Lower Sacramento Basin

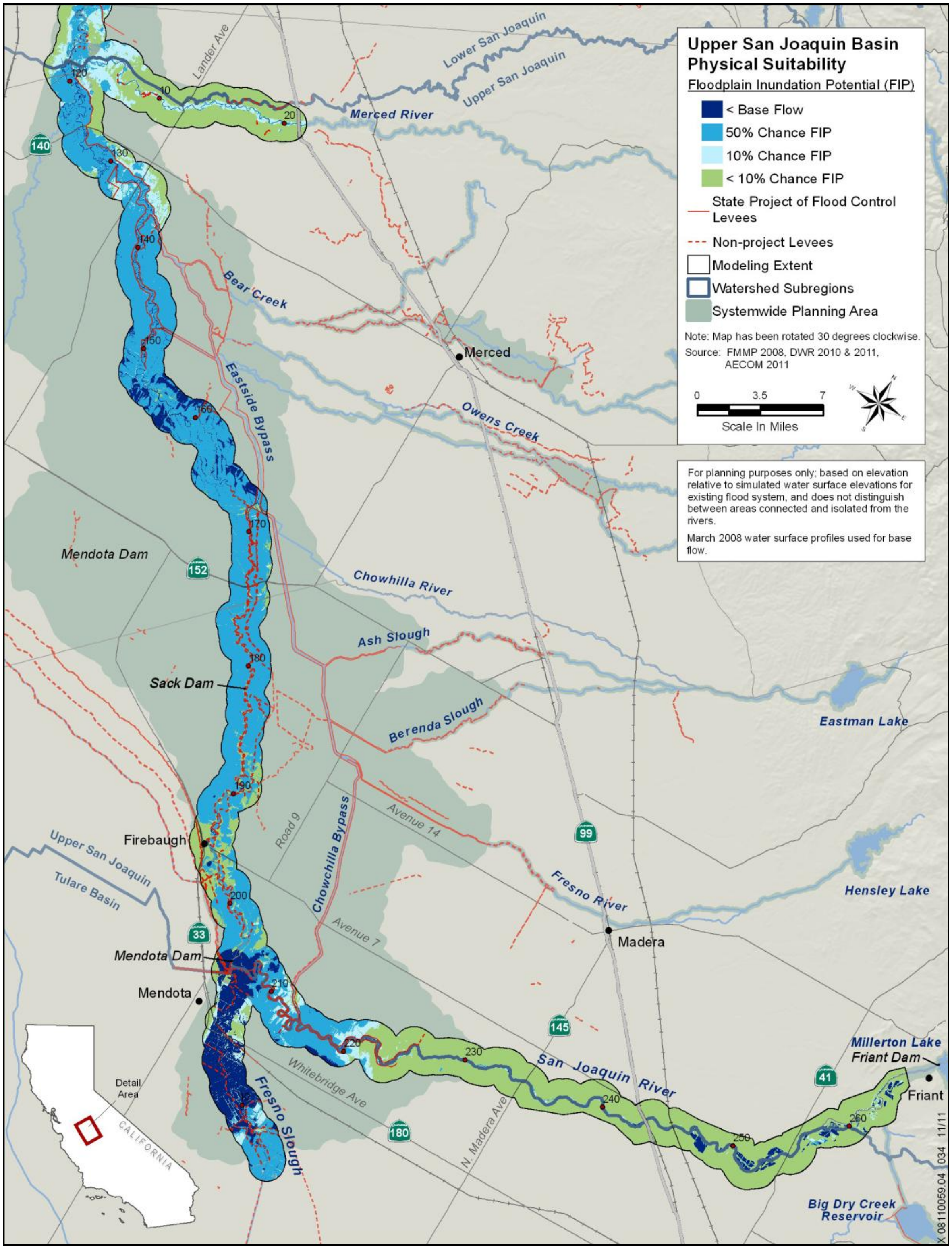

Figure 3-17. Floodplain Inundation Potential of River Corridors in the Upper San Joaquin Basin

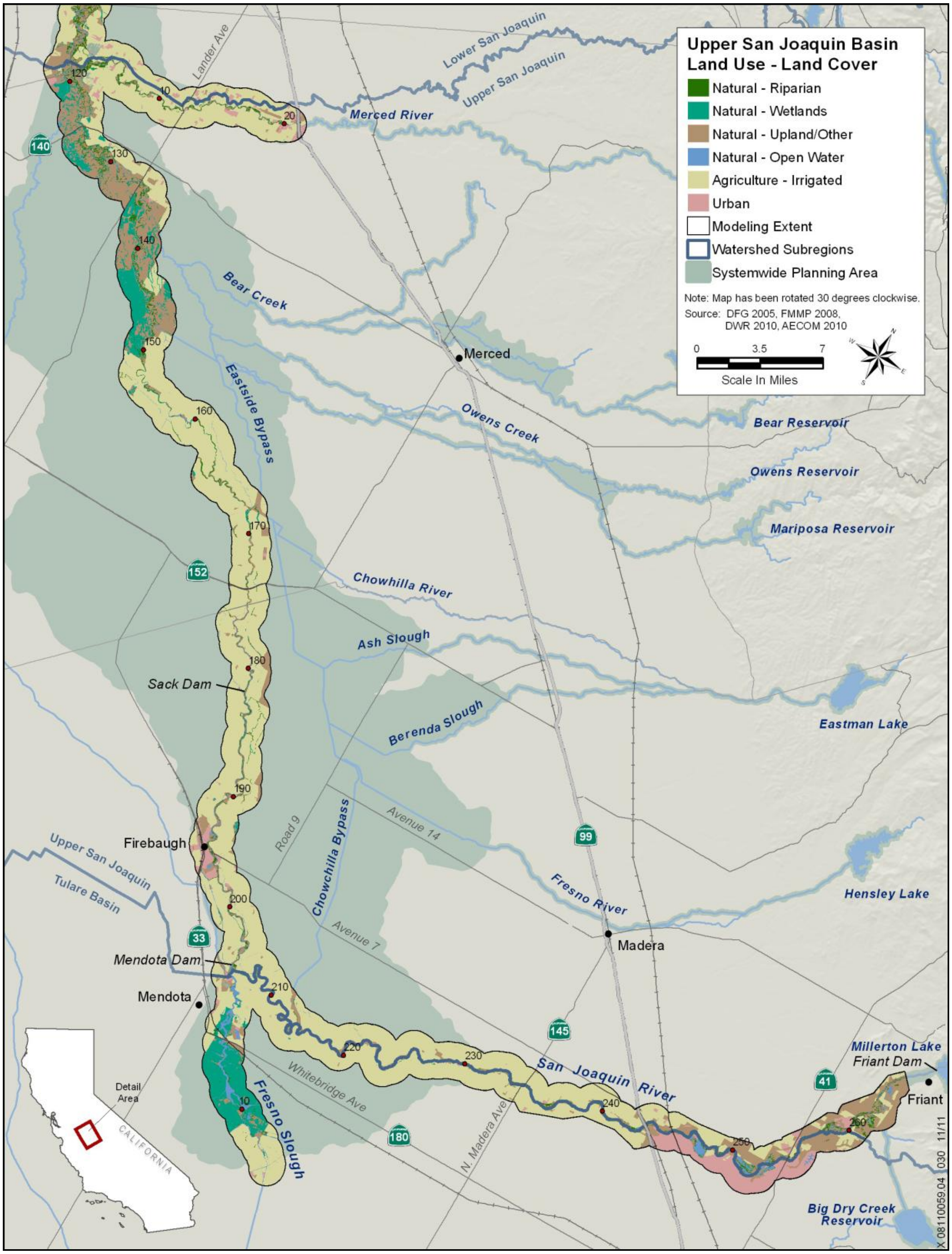

Figure 3-18. Land Use/Land Cover of River Corridors in the Upper San Joaquin Basin

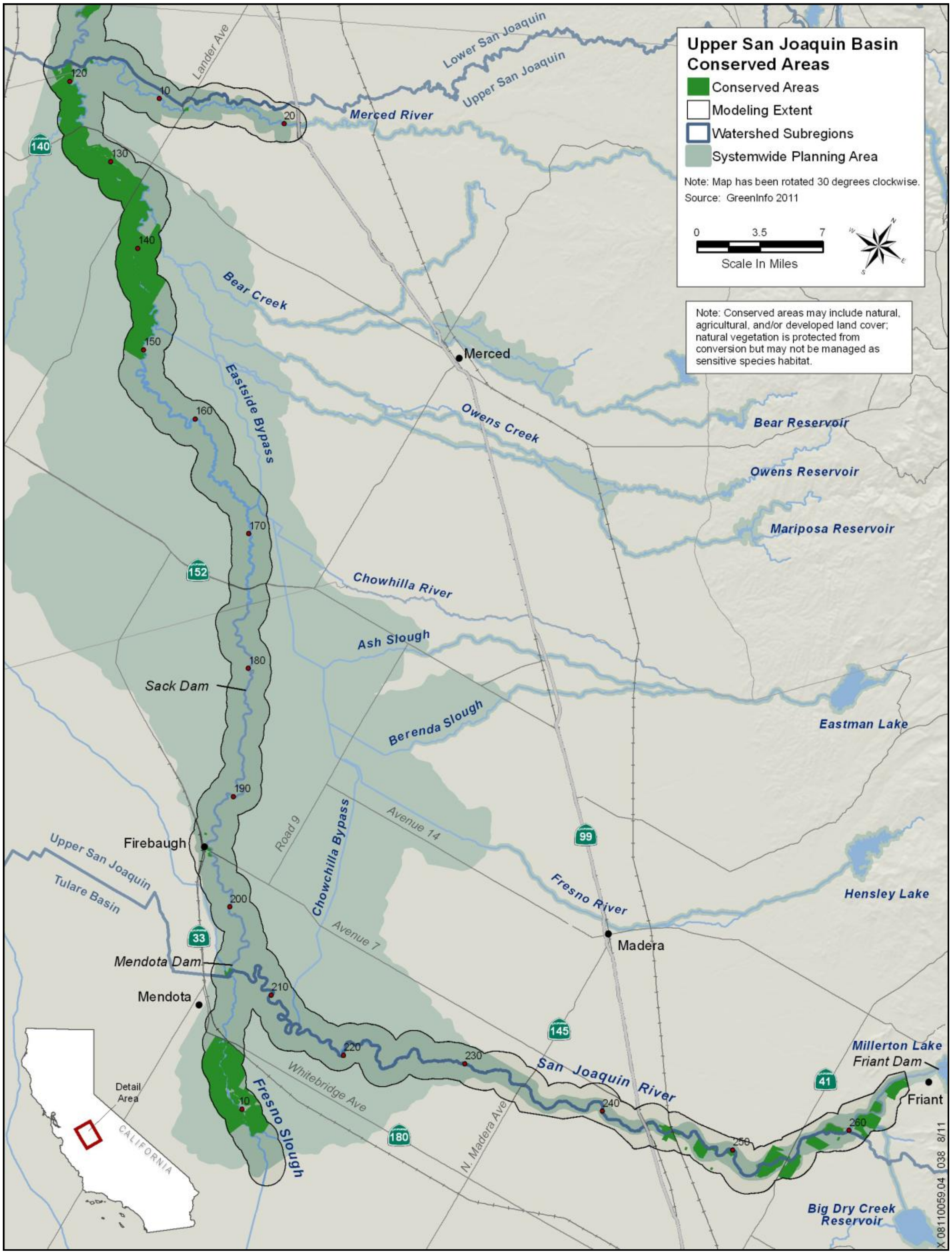

Figure 3-19. Conserved Areas of River Corridors in the Upper San Joaquin River Basin

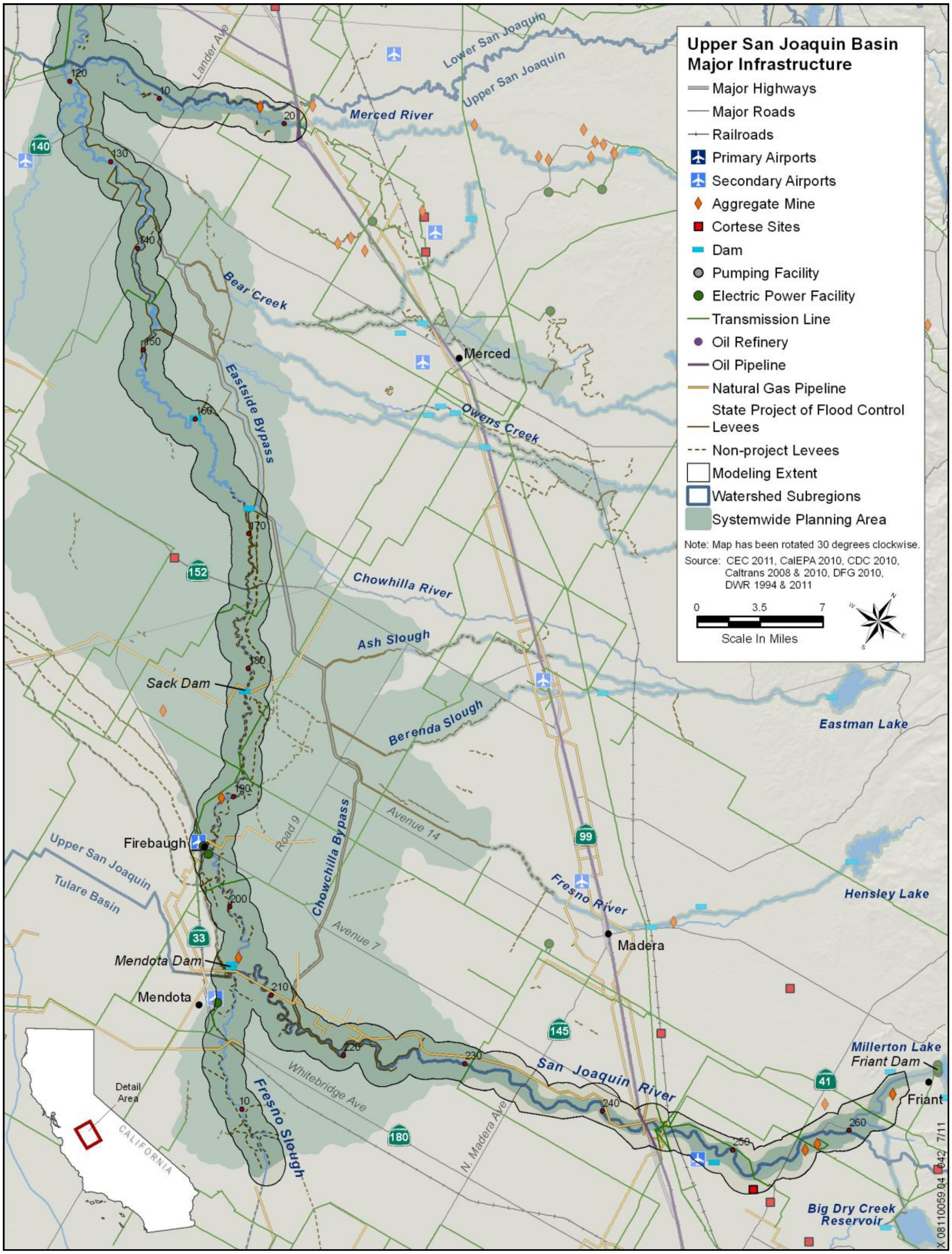

Figure 3-20. Major Infrastructure in River Corridors in the Upper San Joaquin Basin

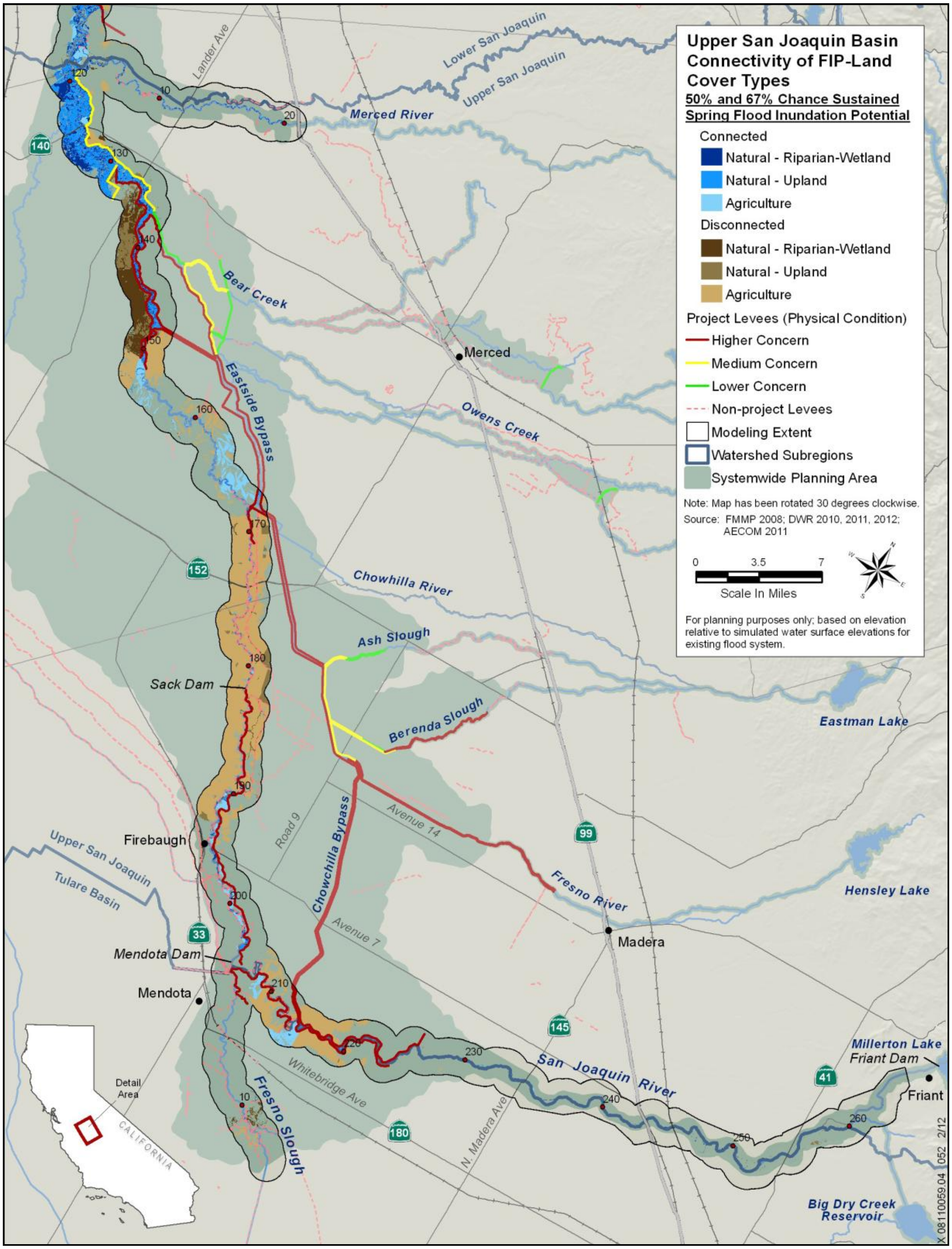

Figure 3-21. Connectivity of FIP-Land Cover Types in the Upper San Joaquin Basin

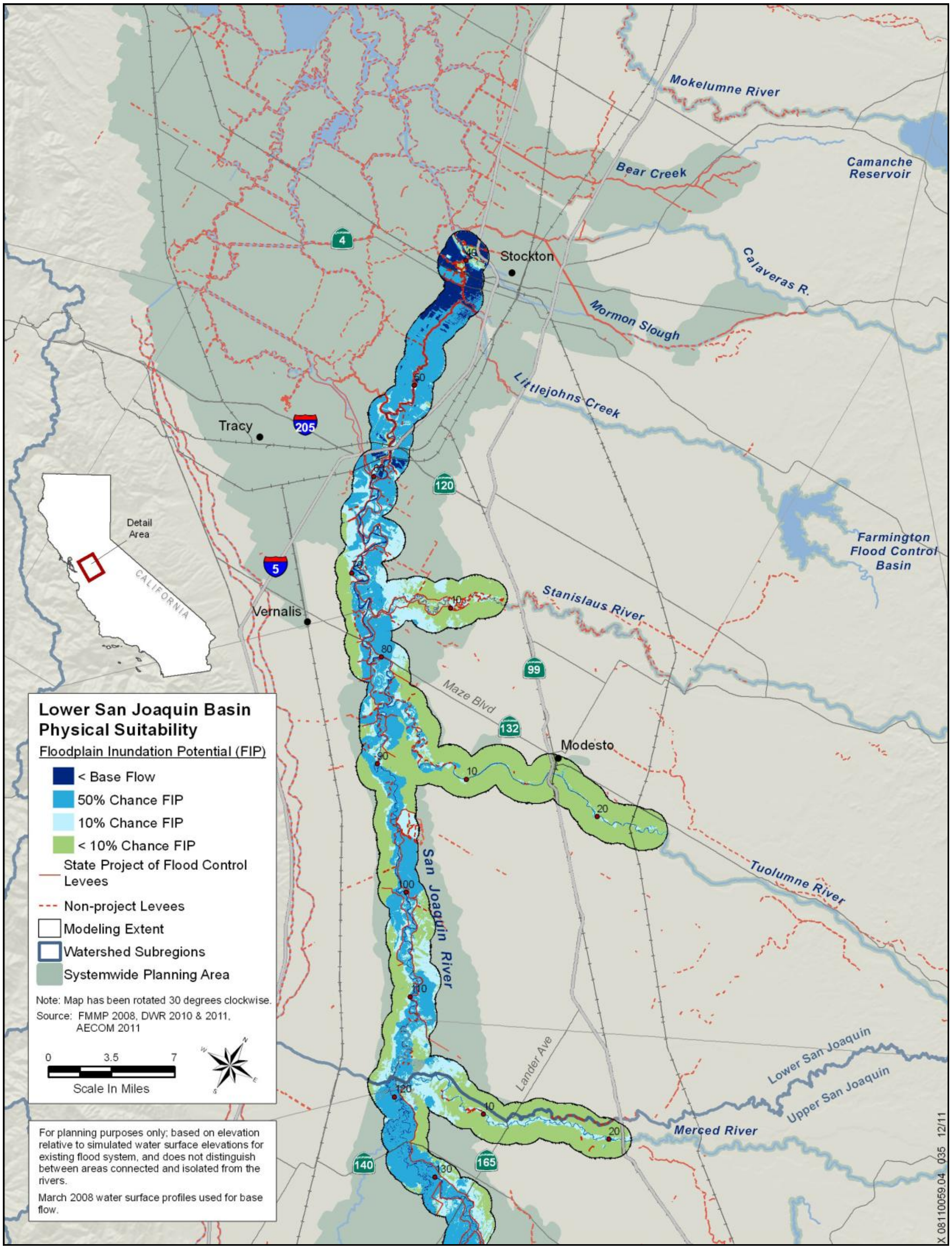

Figure 3-22. Floodplain Inundation Potential of River Corridors in the Lower San Joaquin Basin

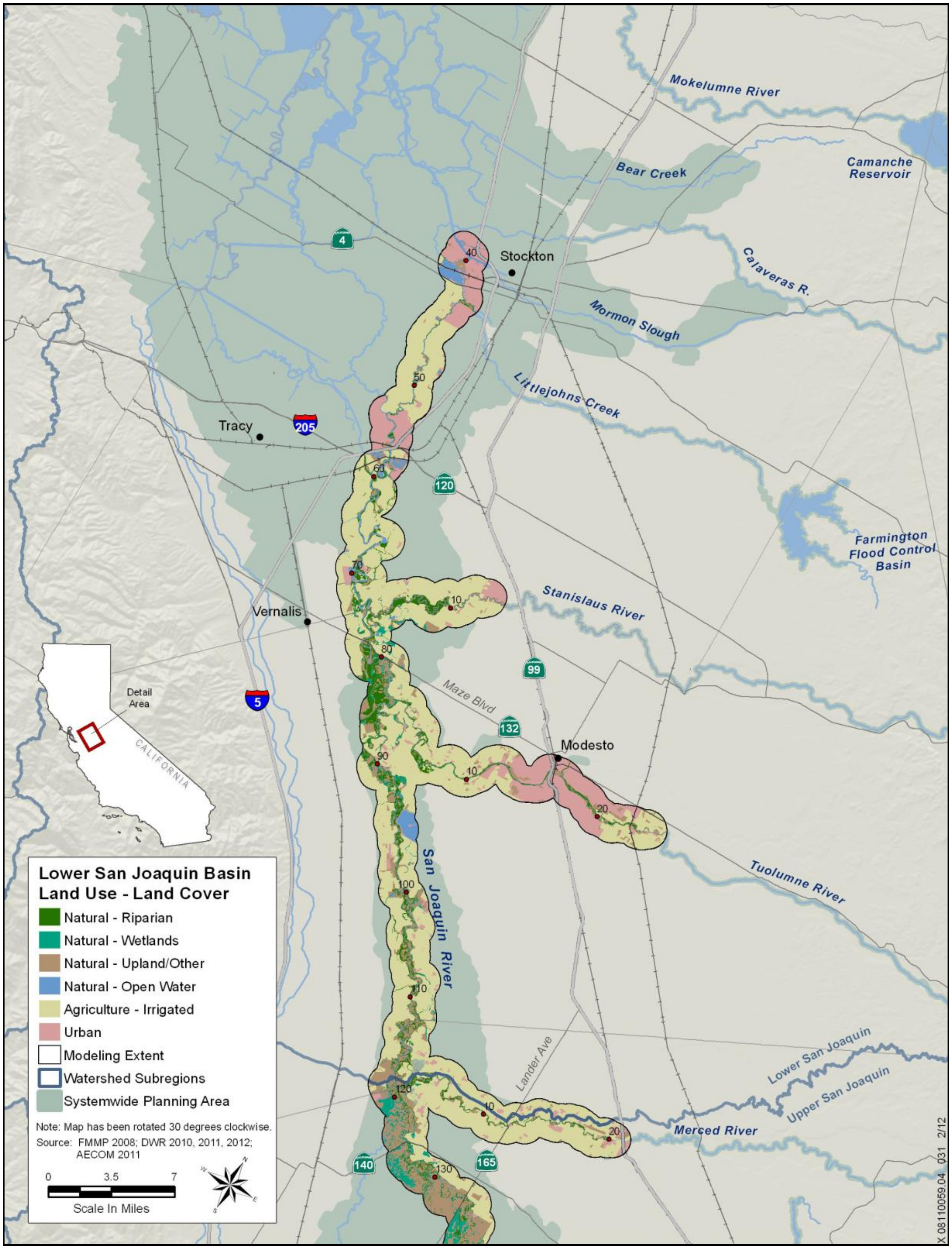

Figure 3-23. Land Use/Land Cover of River Corridors in the Lower San Joaquin Basin

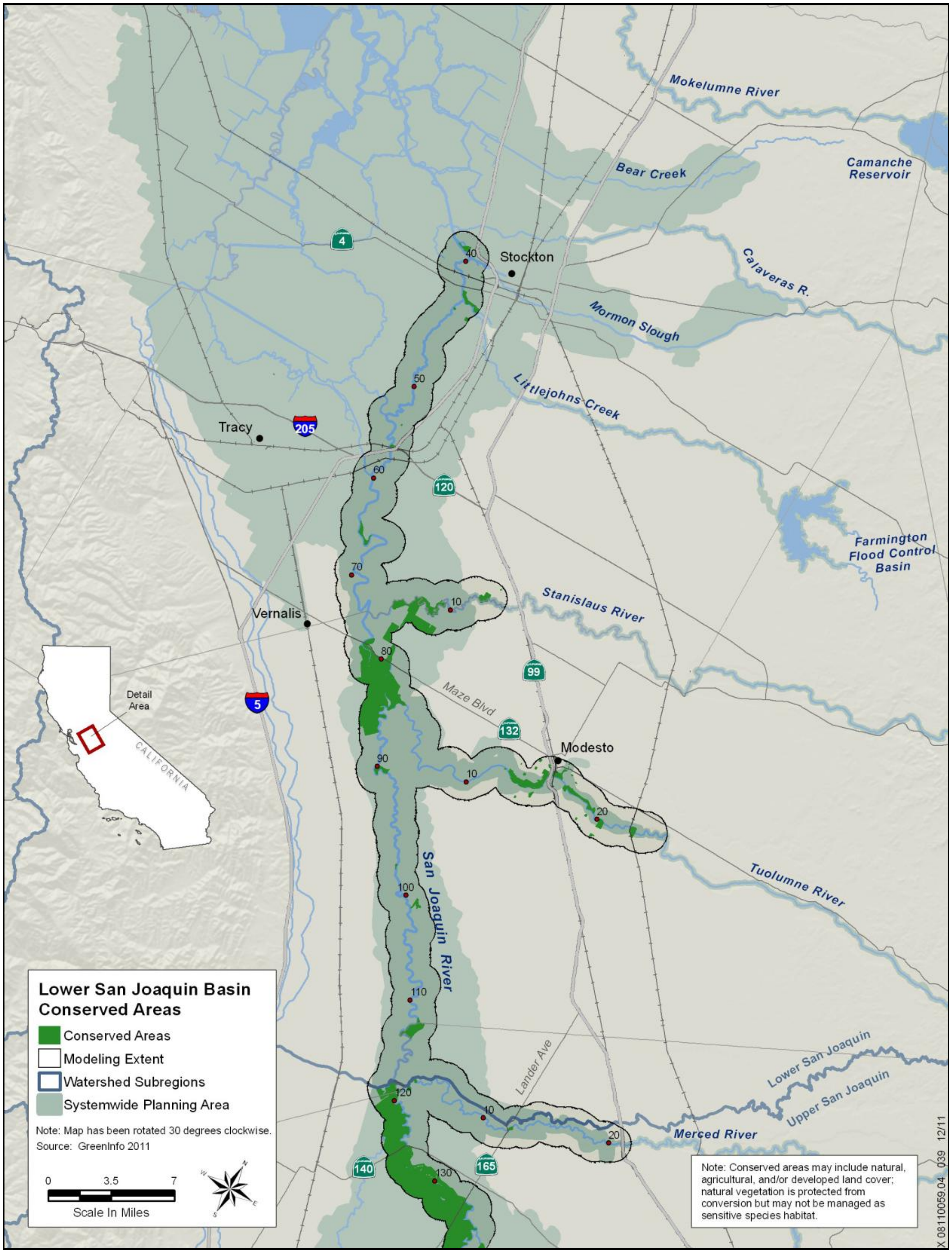

Figure 3-24. Conserved Areas of River Corridors in the Lower San Joaquin Basin

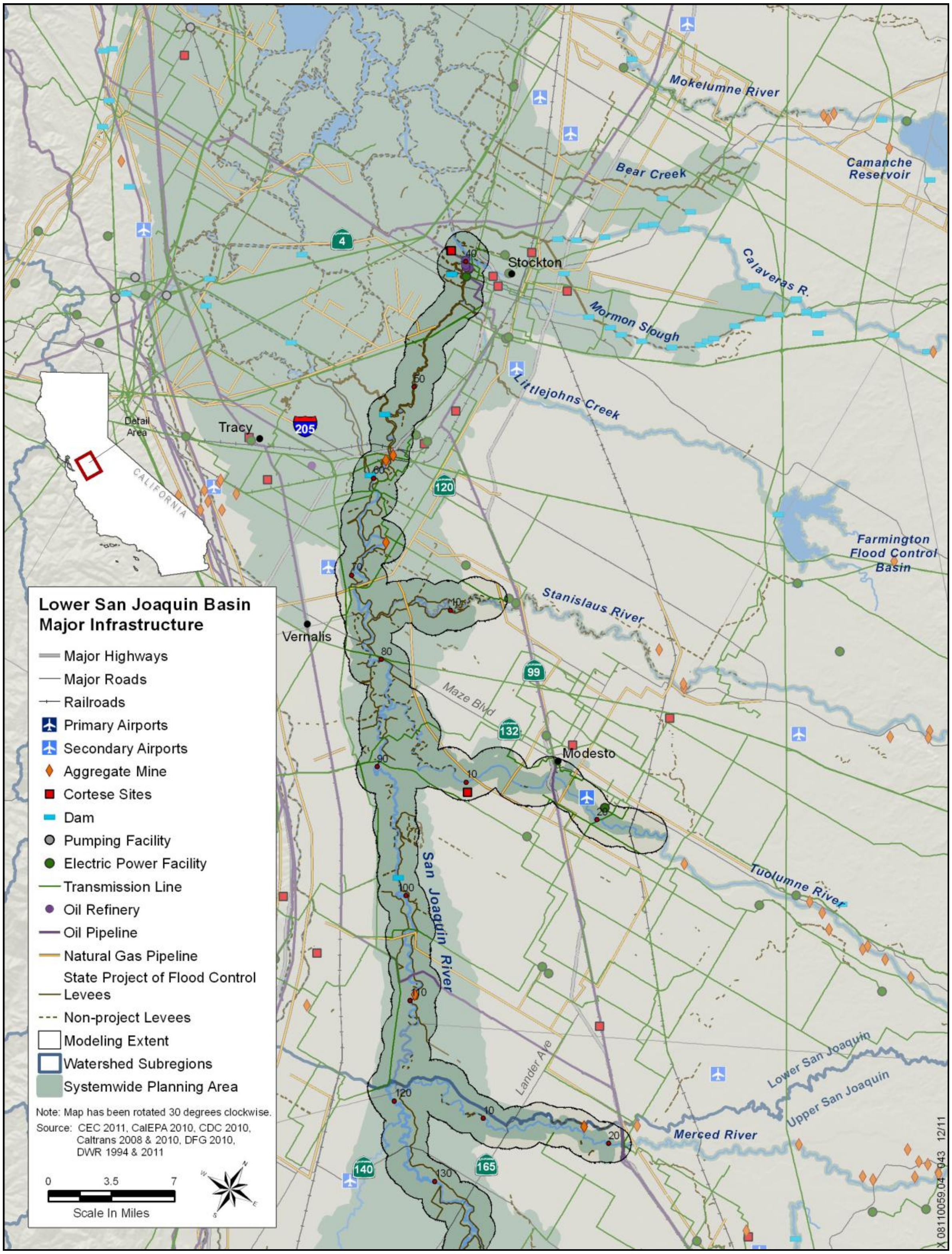

Figure 3-25. Major Infrastructure in River Corridors in the Lower San Joaquin Basin

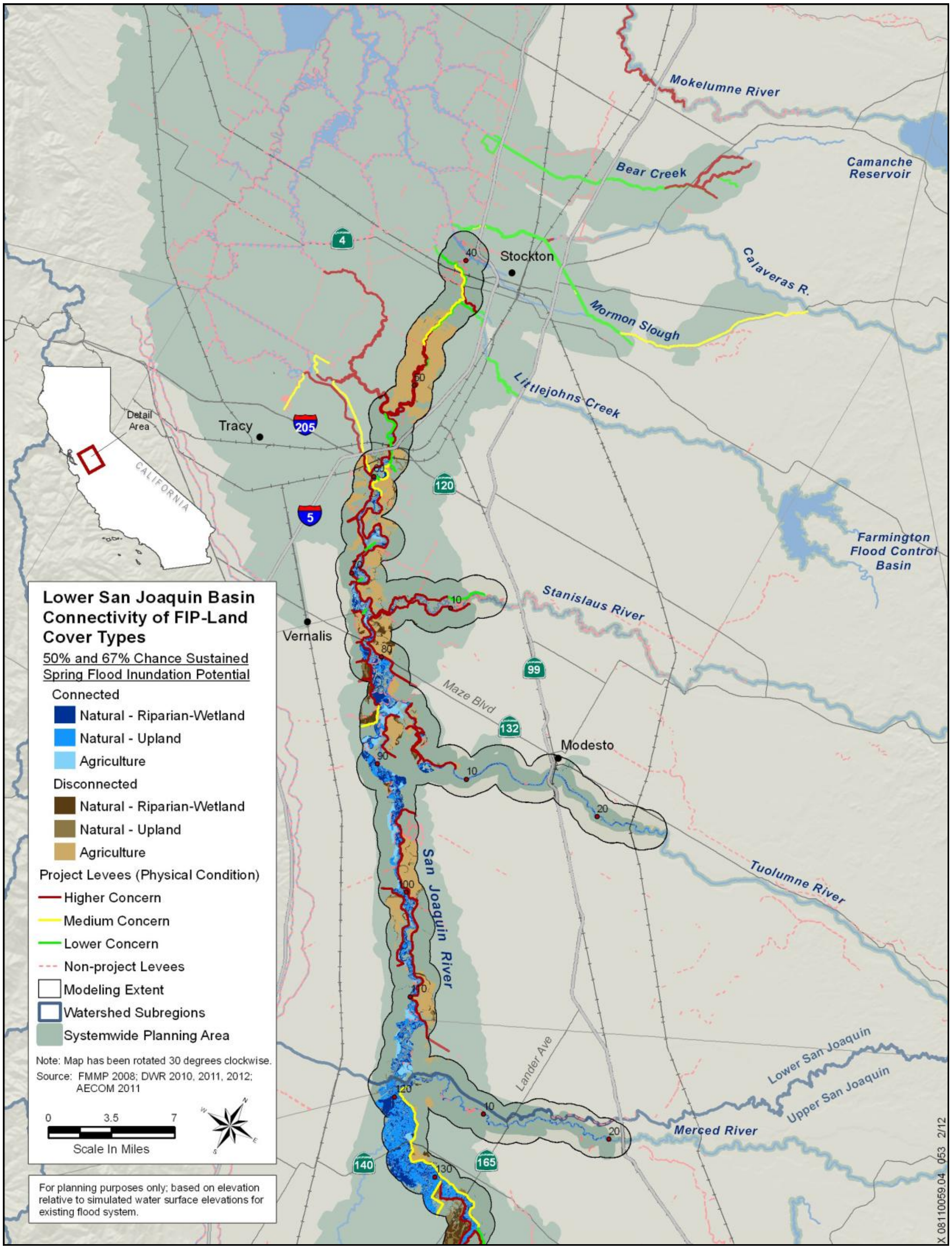

Figure 3-26. Connectivity of FIP-Land Cover Types in Lower San Joaquin Basin

Table 3-1. Floodplain Inundation Potential of Sacramento River

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance Spring[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Upper Sacramento Valley							
Woodson Bridge State Recreation Area–Chico Landing	26,800	7	<1	32	32	28	100
Chico Landing–Colusa	56,400	6	<1	71	12	11	100
Lower Sacramento Valley							
Colusa–Verona	71,400	27	10	61	0	2	100
Verona–American River	24,700	5	25	66	1	2	100
American River–Freeport	17,000	20	28	43	4	4	100
Freeport–Delta Cross Channel	24,800	61	31	5	1	2	100
Delta Cross Channel–Deep Water Ship Channel	16,200	93	3	2	1	2	100
Deep Water Ship Channel–Collinsville	14,600	60	0	3	1	35	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

6 Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

7 Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-2. Nonurban Floodplain Connectivity Percentages for the Sacramento River

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Upper Sacramento Valley						
Woodson Bridge State Recreation Area–Chico Landing	<100	100	0	7,600	86	14
Chico Landing–Colusa	200	98	2	37,900	41	59
Lower Sacramento Valley						
Colusa–Verona	6,800	6	94	42,400	12	88
Verona–American River	5,600	4	96	13,400	5	95
American River–Freeport	2,200	5	95	1,600	10	90
Freeport–Delta Cross Channel	7,100	3	97	1,000	7	93
Delta Cross Channel–Deep Water Ship Channel	400	22	78	200	56	44
Deep Water Ship Channel–Collinsville	<100	75	25	400	71	29

Source: Data generated for this analysis by AECOM, 2011

Notes:

1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

6 Connected to or disconnected (“Discon.”) from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-3. Sacramento River Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]							
	W. Bridge SRA–Chico Landing	Chico Landing–Colusa	Colusa–Verona	Verona–American River	American River–Freeport	Freeport–Delta Cross Channel	Delta Cross Channel–Deep Water Ship Channel	Deep Water Ship Channel–Collinsville
Connected[3]								
Conserved-Riparian/Wetland	7	5	<1	1	<1	<1	<1	<1
Conserved-Natural Upland	1	2	1	1	<1	<1	0	<1
Conserved-Agricultural	1	2	<1	<1	0	<1	<1	<1
Not Conserved-Riparian/Wetland	4	8	2	2	1	<1	<1	<1
Not Conserved-Natural Upland	2	4	1	<1	<1	<1	<1	1
Not Conserved-Agricultural	9	6	3	<1	<1	<1	<1	<1
Connected Subtotal	*24*	*28*	*8*	*4*	*2*	*1*	*1*	*2*
Disconnected[3]								
Conserved-Riparian/Wetland	<1	<1	<1	<1	<1	<1	<1	0
Conserved-Natural Upland	<1	<1	<1	<1	<1	1	<1	<1
Conserved-Agricultural	1	<1	<1	4	0	1	<1	<1
Not Conserved-Riparian/Wetland	<1	1	1	3	<1	<1	<1	<1
Not Conserved-Natural Upland	<1	<1	2	4	8	3	<1	<1
Not Conserved-Agricultural	2	37	57	61	11	26	2	<1
Disconnected Subtotal	*4*	*39*	*61*	*73*	*20*	*32*	*2*	*1*
Total	**28**	**68**	**69**	**77**	**22**	**33**	**3**	**3**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

1 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot. and 67 percent chance Sustained Spring FIP ≤1 foot.). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot, and 10 percent chance FIP ≤1 foot.).

2 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

3 Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-4. Floodplain Inundation Potential of Sacramento River Tributaries

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance Spring[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Feather River							
Thermalito Afterbay–Yuba River	35,800	4	0	41	28	27	100
Yuba River–Bear River	18,600	5	1	86	6	2	100
Bear River–Sutter Bypass	5,800	6	1	89	1	2	100
Sutter Bypass–Sacramento River	8,600	4	12	83	1	1	100
Other Tributaries							
Yuba River	15,400	8	1	11	26	54	100
Bear River	14,600	3	12	37	35	14	100
American River	26,500	4	1	14	28	53	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-5. Nonurban Floodplain Connectivity Percentages for Sacramento River Tributaries

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Feather River						
Thermalito Afterbay–Yuba River	100	100	<1	11,900	69	31
Yuba River–Bear River	200	70	30	14,200	31	69
Bear River–Sutter Bypass	100	87	13	5,100	35	65
Sutter Bypass–Sacramento River	1,000	57	43	7,000	57	43
Other Tributaries						
Yuba River	100	38	62	1,200	47	53
Bear River	1,200	14	86	5,200	15	85
American River	200	98	2	1,100	84	16

Source: Data generated for this analysis by AECOM, 2011

Notes:

1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

6 Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-6. Sacramento River Tributaries Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]						
	Feather River				Other Tributaries		
	Thermalito Afterbay to Yuba River	Yuba River to Bear River	Bear River to Sutter Bypass	Sutter Bypass to Sacramento River	Yuba River	Bear River	American River
Connected[3]							
Conserved-Riparian/Wetland	1	8	4	0	<1	<1	2
Conserved-Natural Upland	1	3	9	0	<1	<1	1
Conserved-Agricultural	<1	1	<1	0	<1	<1	0
Not Conserved-Riparian/Wetland	4	7	9	6	1	3	<1
Not Conserved-Natural Upland	2	2	8	9	2	2	<1
Not Conserved-Agricultural	14	4	2	37	<1	1	<1
Connected Subtotal	*23*	*25*	*32*	*53*	*4*	7	4
Disconnected[3]							
Conserved-Riparian/Wetland	3	0	0	0	<1	<1	<1
Conserved-Natural Upland	1	<1	<1	0	<1	<1	<1
Conserved-Agricultural	<1	<1	<1	0	0	0	0
Not Conserved-Riparian/Wetland	<1	1	<1	<1	<1	1	<1
Not Conserved-Natural Upland	1	3	7	1	2	7	<1
Not Conserved-Agricultural	5	49	49	38	1	30	<1
Disconnected Subtotal	*10*	*53*	*57*	*40*	*5*	*38*	*1*
Total	**33**	**78**	**89**	**93**	**9**	**44**	**5**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-7. Floodplain Inundation Potential of Upper San Joaquin River

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
Friant Dam–State Route 99	22,500	9	1	1	4	85	100
State Route 99–Gravelly Ford	19,400	2	1	2	2	92	100
Gravelly Ford–Chowchilla Bypass	10,500	6	13	29	18	34	100
Chowchilla Bypass–Mendota Dam	8,400	31	26	22	14	7	100
Mendota Dam–Sack Dam	23,800	4	3	66	1	27	100
Sack Dam–Sand Slough Control Structure	14,900	2	10	83	1	5	100
Sand Slough Control Structure–Mariposa Bypass	19,200	20	69	9	0	1	100
Mariposa Bypass–Bear Creek	9,700	2	6	90	1	1	100
Bear Creek–Merced River	16,00	4	4	52	19	20	100

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.

[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).

[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.

[5] Elevation above water surface of 67 percent chance Sustained Spring FIP but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).

[6] Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[7] Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-8. Nonurban Floodplain Connectivity Percentages for Upper San Joaquin River

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
Friant Dam–State Route 99	200	69	31	200	88	12
State Route 99–Gravelly Ford	300	100	0	300	96	4
Gravelly Ford–Chowchilla Bypass	1,400	19	81	2,800	11	89
Chowchilla Bypass–Mendota Dam	2,100	35	65	900	23	77
Mendota Dam–Sack Dam	600	68	32	9,300	13	87
Sack Dam–Sand Slough Control Structure	1,100	17	83	11,700	1	99
Sand Slough Control Structure–Mariposa Bypass	5,800	39	61	1,700	10	90
Mariposa Bypass–Bear Creek	500	57	43	4,800	21	79
Bear Creek–Merced River	700	99	1	7,800	84	16

Source: Data generated for this analysis by AECOM, 2011

Notes:
[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.
[2] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.
[3] Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot.).
[4] Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).
[5] Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot).
[6] Connected to or disconnected ("Discon.") from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under existing conditions).

Table 3-9. Upper San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]								
	Friant Dam–SR 99	SR 99–Gravelly Ford	Gravelly Ford–Chowchilla Bypass	Chowchilla Bypass–Mendota Dam	Mendota Dam–Sack Dam	Sack Dam–Sand Slough Control Structure	Sand Slough Control Structure–Mariposa Bypass	Mariposa Bypass–Bear Creek	Bear Creek–Merced River
Connected[3]									
Conserved-Riparian/Wetland	0	0	0	<1	0	0	<1	3	12
Conserved-Natural Upland	<1	<1	0	0	0	0	<1	5	24
Conserved-Agricultural	0	0	0	0	0	0	0	<1	0
Not Conserved-Riparian/Wetland	1	1	<1	<1	2	1	1	1	2
Not Conserved-Natural Upland	<1	1	4	1	2	1	1	3	5
Not Conserved-Agricultural	<1	<1	1	10	3	<1	11	0	1
Connected Subtotal	*1*	*3*	*5*	*11*	*7*	*2*	*13*	*13*	*44*
Disconnected[3]									
Conserved-Riparian/Wetland	0	0	0	0	0	0	4	25	2
Conserved-Natural Upland	<1	0	0	0	0	0	2	16	3
Conserved-Agricultural	0	0	0	0	0	0	0	<1	<1
Not Conserved-Riparian/Wetland	0	0	<1	<1	1	1	<1	<1	1
Not Conserved-Natural Upland	<1	<1	<1	1	1	6	<1	<1	1
Not Conserved-Agricultural	<1	<1	34	24	33	77	20	0	2
Disconnected Subtotal	*<1*	*<1*	*34*	*25*	*35*	*84*	*26*	*41*	*8*
Total	**1**	**3**	**42**	**48**	**42**	**92**	**39**	**54**	**52**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al,. 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

Table 3-10. Floodplain Inundation Potential of Lower San Joaquin River and Tributaries

Reach	Modeled Area[1] (Acres)	Floodplain Inundation Potential[2] (Percent of Modeled Area)					
		< Base Flow[3]	67% Chance[4]	50% Chance[5]	10% Chance[6]	< 10% Chance[7]	Total
San Joaquin River							
Merced River–Tuolumne River	32,900	3	3	38	20	36	100
Tuolumne River–Stanislaus River	9,100	4	3	47	18	28	100
Stanislaus River–Stockton	35,200	18	15	40	19	9	100
Tributaries							
Merced River	18,800	1	1	4	21	73	100
Tuolumne River	25,700	1	1	5	5	88	100
Stanislaus River	10,700	2	<1	4	37	57	100

Source: Data generated for this analysis by AECOM, 2011

Notes:
1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.
2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011.
3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot).
4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study.
5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).
6 Elevation above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).
7 Elevation above water surface of 10 percent chance flow (i.e., 10 percent chance FIP >1 foot).

Table 3-11. Nonurban Floodplain Connectivity Percentages for Lower San Joaquin River and Tributaries

Reach	Floodplain Inundation Potential[2]					
	67% Chance Sustained Spring[4]			50% Chance[5]		
	Extent (Acres)	Connectivity[6] (Percent)		Extent (Acres)	Connectivity[6] (Percent)	
		Connected	Disconnected		Connected	Disconnected
San Joaquin River						
Merced River–Tuolumne River	1,100	82	18	11,300	52	48
Tuolumne River–Stanislaus River	300	68	32	4,000	40	60
Stanislaus River–Stockton	4,200	9	91	9,300	11	89
Tributaries						
Merced River	100	96	4	500	38	62
Tuolumne River	200	85	15	1,000	49	51
Stanislaus River	<100	83	17	300	30	70

Source: Data generated for this analysis by AECOM, 2011

Notes:

1 Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

2 Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. Connectivity not modeled for areas with 10 percent chance and > 10 percent chance FIP.

3 Elevation below or at water surface elevation of March 2008 base flow (i.e., LiDAR FIP ≤1 foot).

4 Elevation above water surface of base flow but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of EFM (used in pilot study).

5 Elevation above water surface of 67 percent chance spring flow sustained for at least 7 days but below that of 50 percent chance flow (i.e., 67 percent chance Sustained Spring FIP >1 foot. and 50 percent chance FIP ≤1 foot.).

6 Connected to or disconnected (“Discon.”) from river system during a 50 percent chance flow; i.e., modeled as inundated by flood flows under existing conditions).

Table 3-12. Lower San Joaquin Valley Distribution of Nonurban 67 Percent Chance Sustained Spring and 50 Percent Chance FIP by Connectivity, Land Use, and Conservation Status[1]

Landscape Category	Percentage of Evaluated Corridor by Reach[2]					
	San Joaquin River			Tributaries		
	Merced River–Tuolumne River	Tuolumne River–Stanislaus River	Stanislaus River–Stockton	Merced River	Tuolumne River	Stanislaus River
Connected[3]						
Conserved-Riparian/Wetland	1	9	0	<1	<1	<1
Conserved-Natural Upland	1	5	<1	<1	<1	<1
Conserved-Agricultural	0	0	<1	0	0	0
Not Conserved-Riparian/Wetland	7	3	2	1	2	1
Not Conserved-Natural Upland	6	1	<1	<1	<1	<1
Not Conserved-Agricultural	5	1	1	<1	<1	<1
Connected Subtotal	*21*	*20*	*4*	*2*	*3*	*1*
Disconnected[3]						
Conserved-Riparian/Wetland	1	3	0	0	<1	1
Conserved-Natural Upland	<1	2	<1	0	0	<1
Conserved-Agricultural	0	5	<1	0	0	<1
Not Conserved-Riparian/Wetland	1	3	1	<1	<1	<1
Not Conserved-Natural Upland	1	2	1	<1	<1	<1
Not Conserved-Agricultural	14	12	32	1	1	1
Disconnected Subtotal	*17*	*28*	*34*	*2*	*2*	*2*
Total	**38**	**48**	**42**	**4**	**5**	**3**

Source: DFG 1997, DOC 2008, DWR 2010, and Data generated for this analysis by AECOM, 2011

Notes:

[1] Based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.). 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[2] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; percentages are rounded to the nearest percent.

[3] Connected to or disconnected from river system during a 50 percent chance flow (i.e., modeled as inundated by flood flows under 2008 infrastructure and topography).

4.0 Floodplain Restoration Opportunities: Conclusions and Recommendations

This chapter summarizes the relative extent of potential restoration opportunities identified along river reaches based on their physical suitability and existing land cover, and makes general recommendations for the future use of FROA results.

4.1 Conclusions

Restoration opportunities are widespread throughout the 2-mile-wide corridors evaluated along the Sacramento and San Joaquin river systems. Outside of urban areas, there are more than 320,000 acres of floodplain with a 67 percent chance Sustained Spring FIP or a 50 percent chance FIP under the existing flow regime of the Sacramento River system and the flow regime planned by the SJRRP for the San Joaquin River system.

These floodplain areas (which have the potential for frequent inundation) are most limited along several of the major tributaries (e.g., the American, Merced, Tuolumne, and Stanislaus rivers), the upper San Joaquin River from Friant Dam to Gravelly Ford, and the lower Sacramento River downstream of the Delta Cross Channel. Floodplain with 67 percent chance Sustained Spring FIP or a 50 percent chance FIP accounts for less than 5 percent of the evaluated corridors along these reaches. However, because 1 percent of a 2-mile-wide corridor is comparable to corridors about 50 feet wide on each river bank, even these reaches have restoration opportunities (e.g., creation of Shaded Riverine Aquatic habitat) that could have systemwide benefits.

Floodplain with the potential for frequent inundation is much more extensive along other river reaches, providing a greater variety of restoration opportunities. In particular, river reaches differ substantially in the extent of the following combinations of hydrologic connectivity to the river system, nonurban land use/land cover, and FIP that represent different types of restoration opportunities:

- Floodplain hydrologically connected to the river, with riparian or wetland vegetation, and with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP

- Floodplain hydrologically connected to the river, without riparian or wetland vegetation, with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP

- Floodplain hydrologically disconnected from the river with a 67 percent chance Sustained Spring Flow FIP

- Floodplain hydrologically disconnected from the river with a 50 percent chance FIP

Along all evaluated reaches of the Sacramento and San Joaquin river systems, each of these types of floodplain areas exist (Tables 4-1 and 4-2) and their restoration could provide ecologically important benefits. However, those reaches having the most extensive areas of each type probably represent greater and/or more feasible opportunities for large-scale restoration of riverine and floodplain ecosystems. The types of restoration opportunities represented by these floodplain areas and their distribution among river reaches are described further below. Their distribution among river reaches is also displayed in Tables 4-1 and 4-2.

Less than 40 percent of floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP remains hydrologically connected to the river system. Hydrologically connected floodplain is most extensive along the Sacramento River from Woodson Bridge to Colusa, the Feather River from Thermolito Afterbay to the junction with the Sacramento River, and the San Joaquin River from Bear Creek to the junction with the Stanislaus River. Hydrologically connected floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP accounts for 20 percent to 53 percent of the 2-mile-wide corridor along these reaches. The majority of this floodplain has a 50 percent chance FIP and is not frequently inundated by sustained spring flows.

Riparian and wetland vegetation covers only about a third (approximately 34 percent) of the floodplain that has remained connected to the river system, including most connected floodplain with a 67 percent chance Sustained Spring Flow FIP. In many of these areas, channel migration processes have been impeded by revetment, which has reduced habitat values. Similarly, the installation of revetment has reduced the amount of Shaded Riverine Aquatic habitat, and habitat for other species (e.g., bank swallow). Thus, there is an opportunity to restore these areas by revetment removal.

Table 4-1. Restoration Opportunities Along Sacramento River System

Reach	Modeled Area[1] (Acres)	Restoration Opportunity[2] (Percent of Modeled Area)					Notes
		Connected[3]		Disconnected[3]		Total	
		Riparian/ Wetland	Other Land Use/ Land Cover	67% Chance SS FIP[2]	50% Chance FIP[2]		
Sacramento River							
Woodson Bridge–Chico Landing	26,792	11	14	0	4	28	Extensive conserved land, bank swallow, yellow-billed cuckoo
Chico Landing–Colusa	56,442	14	14	<1	39	68	Bank swallow, yellow-billed cuckoo
Colusa–Verona	71,376	3	5	9	52	69	Bank swallow, yellow-billed cuckoo
Verona–American River	24,732	2	1	22	51	77	Extensive infrastructure constraints
American River–Freeport	16,969	1	1	12	8	22	Extensive development and infrastructure
Freeport–Delta Cross Channel	24,784	<1	1	28	4	33	Tidally influenced, in legal Delta
Delta Cross Channel–Deep Water Ship Channel	16,192	<1	1	2	1	3	Tidally influenced, in legal Delta
Deep Water Ship Channel–Collinsville	14,641	1	2	<1	1	3	Tidally influenced, in legal Delta
Feather River							
Thermalito Afterbay to Yuba River	35,830	6	18	<1	10	33	Historical and active gravel pits, fall-run Chinook spawning and rearing, bank swallow, yellow-billed cuckoo
Yuba River to Bear River	18,646	15	9	<1	53	78	Bank swallow
Bear River to Sutter Bypass	5,828	13	19	<1	57	89	Bank swallow, yellow-billed cuckoo
Sutter Bypass to Sacramento River	8,643	6	47	5	35	93	Bank swallow
Other Tributaries							
Yuba River	15,390	1	3	1	4	9	Extensive disturbed area (Yuba Gold Fields)
Bear River	14,612	3		7			Fall-run Chinook spawning and rearing (intermittent)
American River	26,489	3	2	<1	1	5	Extensive development and infrastructure, extensive conserved land, bank swallow, fall-run Chinook spawning and rearing

Source: Data generated for this analysis by AECOM in 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] For nonurban areas and based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring (SS) FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study. 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[3] During 50 percent chance event, simulated under 2008 topography and infrastructure.

Table 4-2. Restoration Opportunities Along San Joaquin River System

Reach	Modeled Area[1] (Acres)	Restoration Opportunity (Percent of Modeled Area)					Notes
		Connected[3]		Disconnected[3]		Total	
		Riparian/Wetland	Other Land Use/Land Cover	67% chance SS FIP[2,]	50% chance FIP[2,]		
San Joaquin River							
Friant Dam to SR 99	22,545	1	<1	<1	<1	1	Extensive development and infrastructure, historical and active gravel pits, potential spawning habitat if salmon reintroduced
SR 99 to Gravelly Ford	19,373	1	2	<1	<1	3	
Gravelly Ford to Chowchilla Bypass	10,511	<1	5	10	24	40	
Chowchilla Bypass to Mendota Dam	8,368	<1	11	16	9	36	Mendota Pool – major infrastructure constraint
Mendota Dam to Sack Dam	23,842	2	5	1	34	42	Mendota Pool – major infrastructure constraint
Sack Dam to Sand Slough	14,895	1	2	6	78	86	
Sand Slough to Mariposa Bypass	19,180	1	12	18	8	39	Carries only local drainage, until modified
Mariposa Bypass to Bear Creek	9,689	5	8	2	39	54	Extensive conserved land
Bear Creek to Merced River	16,263	14	30	<1	8	52	Extensive conserved land
Merced River to Tuolumne River	32,861	8	13	1	17	38	
Tuolumne River to Stanislaus River	9,052	12	8	1	27	48	Riparian woodrat and riparian brush rabbit habitat, extensive conserved land
Stanislaus River to Stockton	35,191	2	2	11	23	38	Extensive development and infrastructure, riparian woodrat and riparian brush rabbit habitat, tidally influenced, in legal Delta
Tributaries							
Merced River	18,782	1	1	<1	2	2	
Tuolumne River	25,666	2	1	<1	2	2	Extensive development and infrastructure
Stanislaus River	10,672	1	<1	<1	2	2	Riparian woodrat and riparian brush rabbit habitat

Source: Data generated for this analysis by AECOM, 2011

Notes:

[1] Data are for a corridor extending 1 mile from each river bank of evaluated rivers; acreages are rounded to the nearest 100 acres and percentages are rounded to the nearest percent.

[2] For nonurban areas and based on potential hydrologic regime using categories described by Williams et al., 2009, as indicated by floodplain inundation potential (FIP) determined using technique of Dilts et al., 2010, and AECOM, 2011. 67 percent chance Sustained Spring FIP represents elevations above water surface of base flow (i.e., March 2008 flows; LiDAR FIP) but at or below that of 67 percent chance spring flow sustained for at least 7 days (i.e., LiDAR FIP > 1 foot, and 67 percent chance Sustained Spring FIP ≤1 foot.); 67 percent chance Sustained Spring FIP corresponds to Frequently Activated Floodplain of Williams et al., 2009, and Salmonid FIP of pilot study. 50 percent chance FIP represents elevations above water surface of 50 percent chance flow but below that of 10 percent chance flow (i.e., 50 percent chance FIP >1 foot. and 10 percent chance FIP ≤1 foot).

[3] During 50 percent chance event, simulated under 2008 topography and infrastructure.

In many areas of floodplain hydrologically connected to the river system and lacking riparian vegetation, riparian vegetation could be established through natural processes or plantings. However, the SPFC often has insufficient capacity to allow for the increased roughness (i.e., resistance to water flow) of additional riparian vegetation. Thus, there is an opportunity to facilitate future restoration of these areas by increasing the capacity of the SPFC to allow for the increased roughness of riparian vegetation.

More than 60 percent of floodplain with a 67 percent chance Sustained Spring Flow or a 50 percent chance FIP is hydrologically disconnected from the river system by levees. Riparian and wetland vegetation cover only several percent of this disconnected floodplain. Also, less than 5 percent of this disconnected floodplain is conserved along most reaches. Reconnecting these floodplains, particularly areas with a 67 percent chance Sustained Spring FIP, to the river system could provide higher quality habitat for salmonids, and other ecological functions.

Disconnected areas with a 67 percent chance Sustained Spring Flow FIP are relatively extensive along the Sacramento River from Verona to the Delta Cross Channel, and along several reaches of the San Joaquin River: Gravelly Ford to Mendota Dam, Sand Slough to the Mariposa Bypass, and from the Stanislaus River to Stockton. However, major infrastructure constraints are also extensive along several of these reaches, in particular along the Sacramento River from Verona to Freeport. Thus, large-scale opportunities to restore these areas by setting back levees or otherwise reconnecting these areas to the river system are limited.

Extensive areas of disconnected floodplain with a 50 percent chance FIP are more widespread along the Sacramento and San Joaquin river systems than areas with a 67 percent chance FIP. Floodplain with a 50 percent chance FIP are extensive along the Sacramento River from Chico Landing to the junction with the American River; the lower Feather River, particularly from the junction with the Yuba River to the junction with the Sacramento River; and much of the San Joaquin River from Gravelly Ford to Stockton.

The feasibility, costs, and benefits of restoring any of these areas are strongly influenced by their relationship to CVFPP projects and policies, and by the content of the Central Valley Flood System Conservation Strategy (CVFSCS). Also, potential benefits differ qualitatively among reaches because sensitive species differ in their distribution. For example, reaches providing salmonid spawning habitat do not provide delta smelt habitat, and reaches providing riparian brush rabbit habitat may not provide bank swallow habitat. Consequently, the identification and prioritization of restoration opportunities are both part of the continuing development of the overall CVFPP and of the development of species-focused conservation planning and corridor management strategies, as described in the Conservation Framework of the 2012 CVFPP.

Based in part on the results of this FROA, DWR is identifying, prioritizing, and further developing specific restoration opportunities for these river reaches. Opportunities are being identified and prioritized on the basis of their potential ecological, flood management, and other benefits (e.g., reduced maintenance and regulatory compliance costs); cost; and regulatory, institutional, technological, and operational feasibility.

4.2 Recommendations

The following are recommendations for future use of the results of this analysis for development of CVFPP projects and the CVFSCS:

- Consider FROA results during project planning as general indicators of potential ecosystem benefits.
- Conduct additional stakeholder interviews to develop a more comprehensive compilation of stakeholder-identified projects.
- Apply FROA results to evaluate the ecosystem effects of alternative actions.
- Apply FROA results to CVFSCS development as a component of baseline ecosystem conditions together with a more comprehensive summary of riverine and riparian-associated species.
- Use FROA results to identify and/or prioritize sites for preservation or restoration.
- Integrate FROA results with mapping of SRA, revetment, and natural banks to more specifically consider reach-scale opportunities for restoring channel migration.

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6.0 Abbreviations and Acronyms

cfs	cubic feet per second
CNDDB	California Natural Diversity Database
Comprehensive Study	Sacramento and San Joaquin River Basins Comprehensive Study
CVFED	Central Valley Floodplain Evaluation and Delineation
CVP	Central Valley Project
CVFPP	Central Valley Flood Protection Plan
CVFSCS	Central Valley Flood System Conservation Strategy
Delta	Sacramento-San Joaquin Delta
DEM	digital elevation model
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EFR	Ecosystem Function Relationship
ESRI	Environmental Systems Research Institute, Inc.
FIP	floodplain inundation potential
FROA	Floodplain Restoration Opportunity Analysis
GIS	geographic information system
HAA	Habitat Analysis Areas
HAR	Height Above River
HEC-DSS	Hydrologic Engineering Center's Data Storage System
HEC-EFM	Hydrologic Engineering Center's Ecosystem Functions Model
HEC-GeoRAS	Hydrologic Engineering Center's River Analysis System
HEC-RAS	Hydrologic Engineering Center's River Analysis System
LiDAR	Light Detection and Ranging
MTL	Mean Tidal Level
MWH	MWH Americas, Inc.
NAVD88	North American Vertical Datum 1988

NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
RM	River Miles
SacEFT	Sacramento River Ecological Flows Tool
SJRRP	San Joaquin River Restoration Program
SPFC	State Plan of Flood Control
SR	State Route
SRA	State Recreation Area
UPID	Union Pacific Interceptor Canal
USACE	U.S. Army Corps of Engineers
USACE-HEC	U.S. Army Corps of Engineers Hydrologic Engineering Center
USGS	U.S. Geological Survey
VELB	Valley elderberry longhorn beetle

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